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Methods Paper: Calculation of the Environmental Impact of KfW's Clean Transport Projects

Michel Allekotte, Marie Colson,
Felix Spathelf

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List of Abbreviations

ACU	Air Conditioning Unit
APU	Auxiliary power unit
BAU	Business-as-usual
BMUV	Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection)
BMWK	Bundesministerium für Wirtschaft und Klimaschutz (Federal Ministry for Economic Affairs and Climate Action)
CNG	Compressed natural gas
CO	Carbon monoxide
EF	Emission factor
EIB	European Investment Bank
FI	Financial institution
FC	Financial cooperation
GHG	Greenhouse gas
GPU	Ground power unit
HEV	Hybrid electric vehicle
ICEV	Internal combustion engine vehicle
IFI	International financial institution
IK	Individualfinanzierung & Öffentliche Kunden
IPCC	Intergovernmental Panel on Climate Change
IPEX	International Project- and Export Finance
INFRA	Emissions from infrastructure (construction, maintenance and end-of-life)
KfW	Kreditanstalt für Wiederaufbau

LCV	Light commercial vehicle (GVWR ≤ 3,5t)
LPG	Liquefied petroleum gas
MAT	Emissions from construction, maintenance and end-of-life of vehicles
IMT	Individual motorised transport
NaMo	Nachhaltige Mobilität (sustainable mobility)
NMT	Non-motorised transport
NMVOC	Non-methane volatile organic compounds
NO_X	Nitrogen oxides
LDPT	Long-distance public transport
LPT	Local public transport
PT	Public transport
PCAF	Partnership for Carbon Accounting Financials
PHEV	Plug-in hybrid electric vehicle
pkm	passenger kilometre
PM	Particular matter
HGV	Heavy goods vehicle (GVWR > 3,5t)
tkm	tonne-kilometre
TREMOD	Transport Emission Model
TTW	Tank-to-wheel
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute
WTT	Well-to-tank
WTW	Well-to-wheel
GVWR	Gross vehicle weight rating

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1 Introduction

As awareness of the importance of the transition to a climate-neutral society grows worldwide, the key role of financial institutions in the global response to the climate crisis is increasingly recognized. Calculating greenhouse gas (GHG) and air pollutant emissions from the investment activities of financial institutions is an important step that enhances the transparency of the climate impacts of financial decisions and can improve financial institutions' understanding of their climate-related impact. Consequently, this will broaden the way financial institutions assess the impact of their portfolios and could influence future financing decisions.

The Kreditanstalt für Wiederaufbau (KfW) provides impulses for the economy, society, and ecology in Germany and Europe, as well as globally, particularly in the areas of small and medium-sized enterprises, entrepreneurship, environmental protection, housing, infrastructure, educational promotion, project and export financing, and development cooperation. The KfW Bank Group, along with its subsidiaries DEG, IPEX, and KfW Capital, plays a leading role among development banks worldwide.

A central element of KfW's financing activities is the fight against climate change through the funding of greenhouse gas reduction measures. To evaluate the impact of these measures, uniform methodologies for calculating emission reductions are being developed across the group for the sectors of energy efficiency, renewable energies, and transport & mobility, which will be further refined in a second step.

When accounting for GHG and air pollutant emissions, it is important to distinguish between absolute and relative emissions. Emissions that actually occur and can therefore be measured, at least in principle, are referred to as absolute emissions. On the one hand, these arise directly from the business operations of financial institutions, such as from the heating and electricity consumption of buildings or from business travel. On the other hand, emissions resulting from investment activities are also taken into account. One example is a loan for the construction of a fast-charging station for electric vehicles. The emissions generated, among other things, by the establishment and operation of the charging station are reported by the financial institution. The absolute emissions correspond to the carbon footprint and are disclosed in sustainability reports.

In contrast, relative emissions are a purely theoretical concept. They describe how the emission output changes due to a project. Since they are calculated by comparing the absolute emissions of the project with those of a hypothetical reference scenario without project implementation, they are not a physically measurable quantity. Nevertheless, determining relative emissions is very helpful, as it allows for the quantification of emission reduction effects and their relation to the effort (loan amount). Accordingly, financial institutions can report the relative emissions of their investment activities in "Impact Reports". In the aforementioned example regarding charging stations, the determination of relative emissions would quantify how much emissions are reduced by enabling the operation of electric vehicles, which emit less compared to conventional vehicles.

The aim of this methodology is to account for relative greenhouse gas and air pollutant emissions in order to quantify the effects of investment activities. The relative emissions are calculated ex-ante (i.e., before the project is realized) from the difference in absolute emissions in the following two scenarios:

- With-Project Scenario: Absolute emissions generated by the project
- Without-Project Scenario (Baseline-/BAU Scenario): What would happen without the project? What would the absolute emissions be in this case?

Chapter 2 describes existing methodologies, particularly those from the financial sector, which form the basis for the approach presented in Chapter 3. This includes discussions on the system boundaries, the key metrics for accounting for transport projects, the design of the BAU scenario, and the factor for attributing reductions to KfW. The proposed methodology was developed in the context of the "Sustainable Mobility" (NaMo) loan program of the IK business area and with the involvement of IPEX Bank, and it is generally applicable to transport projects across the entire KfW Group. Finally, Chapter 4 contains explanations of the detailed procedure and data query, which were developed using the example of the "Sustainable Mobility" program.

2 Overview of Existing Methodologies for Determining GHG Emissions

The methodology presented in this report is designed to calculate GHG and air pollutant reductions (relative emissions) associated with KfW loans for the transport sector. It is based on a methodology developed by ifeu in collaboration with KfW Development Bank (**KfW FC**) for determining GHG emissions and reductions from projects funded by KfW FC in the transport sector (methodology not published). Additionally, the standard of the Partnership for Carbon Accounting Financials (**PCAF**) – Part A: Financed Emissions (PCAF 2022) and the guidelines of International Financial Institutions (**IFI**) for GHG calculations in the transport sector (IFI TWG 2015), which each refer to the **GHG Protocol** (Greenhalgh et al. 2005), provide the framework within which this methodology has been developed. The mentioned methodologies focus exclusively on greenhouse gases; however, the fundamental approach can largely be applied to air pollutants as well.

This chapter presents the reference methodologies and relevant definitions for accounting for both absolute emissions (partially for informational purposes, as relative emissions are the focus of this methodological report) and relative emissions. In Chapter 3, the foundations of the KfW methodology for determining GHG and air pollutant reductions in the transport sector will be developed based on the methodologies presented below.

2.1 Reference Methodologies

The following outlines the mentioned methodological references. It is important to note that the PCAF standard is very detailed but focuses on projects in the energy sector, while the IFI has produced a paper specifically for the transport sector, which is relatively concise. Additionally, the PCAF standard concentrates on the calculation of absolute GHG emissions, meaning that the guidelines can generally only be indirectly applied to the calculation of relative emissions conducted here.

2.1.1 GHG Protocol

The GHG Protocol provides a comprehensive, globally standardized framework for calculating GHG emissions from the private and public sectors, from value chains, and from emission reduction measures. It is based on a 20-year partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD).

The GHG Protocol serves as the foundation for all methodologies listed here and has been further developed or adapted for financial institutions. Of particular relevance is the GHG Protocol report "Corporate Value Chain (Scope 3) Accounting and Reporting Standard" (WRI und WBCSD 2011).

2.1.2 IFI Guidelines for GHG Calculations in the Transport Sector

With the "International Financial Institution Framework for a Harmonised Approach to Greenhouse Gas Accounting" (IFI 2015) the IFIs engaged in development cooperation agreed on a harmonized approach to greenhouse gas accounting at the project level. This was supplemented by the paper "IFI Joint Approach to GHG Assessment in the Transport Sector" (IFI TWG 2015), which specifically addresses the transport sector.

Fundamental principles were established to provide a framework for GHG accounting of transport projects. Transport projects are defined as all types of projects that enable or involve the transportation of goods and people.

Furthermore, the principles agreed upon in 2015 were expanded and elaborated in (IFI TWG 2021), particularly regarding the design of the BAU scenario. Additionally, the mentioned paper includes calculation examples that illustrate the application of the methodological principles.

2.1.3 PCAF Standard Part A: Financed Emissions

The Partnership for Carbon Accounting Financials (PCAF) is a global initiative of financial institutions that has developed a standard for accounting for GHG emissions. Founded in 2015 by Dutch financial institutions, PCAF expanded to North America in 2018, and by 2019, banks from around the world had joined. The "Global GHG Accounting and Reporting Standard Part A - Financed Emissions" (PCAF 2022) provides a methodological foundation for seven asset classes. The goal is to create a transparent, harmonized methodology for reporting emissions from investments and loans.

For financing in the transport sector, two of the seven asset classes are relevant: "Project Finance"[1] and "Motor Vehicle Loans".

- "Project finance" includes balance sheet-effective loans for or shares in projects with a specific purpose, meaning that the use of funds is known in the context of the GHG Protocol. The financing is intended for a specific activity or a series of activities, such as the construction and operation of a railway line.
- "Motor vehicle loans" refer to balance sheet-effective loans and credit lines for specific purposes, meaning that the utilisation of the funds is known in the sense of the GHG Protocol. They are provided to businesses and consumers for the financing of one or more motor vehicles.

2.1.4 KfW FC Methodology for Determining GHG Emissions and Reductions

Within the KfW Bank Group, KfW FC is responsible for development cooperation. The Competence Centre Climate and Energy of KfW FC describes the underlying methodology for

[1] Definition of the GHG Protocol: Project financing is defined in the Scope 3 Standard as the long-term financing of projects (e.g., infrastructure and industrial projects) by the reporting company either as an equity investor (sponsor) or as a debt investor (financier) (WRI und WBCSD 2011).

greenhouse gas accounting of projects funded by KfW on behalf of the German Federal Government and other donors, including the European Union, within the framework of Financial Cooperation (FC) (KfW Competence Centre Climate and Energy 2022). The methodology defines a framework for the ex-ante estimation of GHG emissions from FC projects that can be assessed and accounted for. Project-specific data is presented in the project evaluation documents in accordance with the requirements of the funding organization.

2.2 Definitions

The key terms are defined by KfW FC in (KfW Competence Centre Climate and Energy 2022) and are adopted in this methodology:

- "Absolute emissions" are emissions caused by a project. For example, KfW finances new electric trains and the associated overhead lines. The required electricity is provided by the country's power plants, which – depending on the energy mix – cause a certain level of emissions. Therefore, the trains financed by KfW result in absolute emissions.

- "Relative emissions" (emission reductions) describe the difference in absolute emissions between a "with" project scenario and a "without" project scenario. For example, the financed trains replace an existing system of diesel trains that caused higher emissions than the electric trains. The difference between the absolute emissions of the system with project implementation and the absolute emissions in the scenario without the project represents the emission reduction.

- "Avoided emissions" are emission reductions compared to an expected future increase in emissions that would have occurred without the project. For example, KfW invests in the preservation of a natural ecosystem. This prevents deforestation and thus emissions in the future. Avoided emissions correspond to the above concept of "relative emissions".

- "CO_2 sequestration" or „negative absolute emissions" occur when a project actually removes existing greenhouse gases from the atmosphere, such as through reforestation. This real reduction in the concentration of greenhouse gases is clearly distinct from the theoretical concept of relative emissions or emission reductions. In the latter case, GHGs are generally still emitted, just less than in a reference scenario. CO_2 sequestration typically does not play a role in the transport sector.

2.3 Emission Accounting

2.3.1 Reporting on Carbon Footprint and Avoided Emissions

To achieve the goals of the Paris Agreement, financial institutions have to actively seek activities that enable a reduction in absolute emissions. For this purpose, it is necessary for them to report the absolute emissions of their financing. Reporting on relative (as well as sequestered) emissions, on the other hand, is optional. If a financial institution chooses to report relative emissions, this has to be done separately from the absolute emissions (PCAF 2022).

According to (IFI TWG 2015) the accounting should focus on CO_2 emissions, as these constitute the significant portion of GHG emissions. In the transport sector, CO_2 is the primary greenhouse gas (Germany: approximately 97% of climate impact[1]).

2.3.2 Allocation of Emissions to Scopes

The GHG Protocol has introduced the Scope system to categorize absolute GHG emissions (see Figure 1). The division into scope 1, scope 2, and scope 3 emissions always refers to the reporting company. Scope 1 emissions correspond to the direct emissions of the company, e.g., from the operation of company-owned diesel vehicles. Indirect emissions are divided into scope 2 (related to electricity, steam, heating, and cooling for own use) and scope 3 (other indirect emissions).

Scope 3 is further divided into different categories. A financial institution has to report the emissions caused by its financing in scope 3 – category 15 (Investments). Since the scope system is only used for the classification of absolute emissions, and this report focuses on determining relative emissions, the scopes will not be further discussed here. More information on this topic can be found in Appendix 5.2.

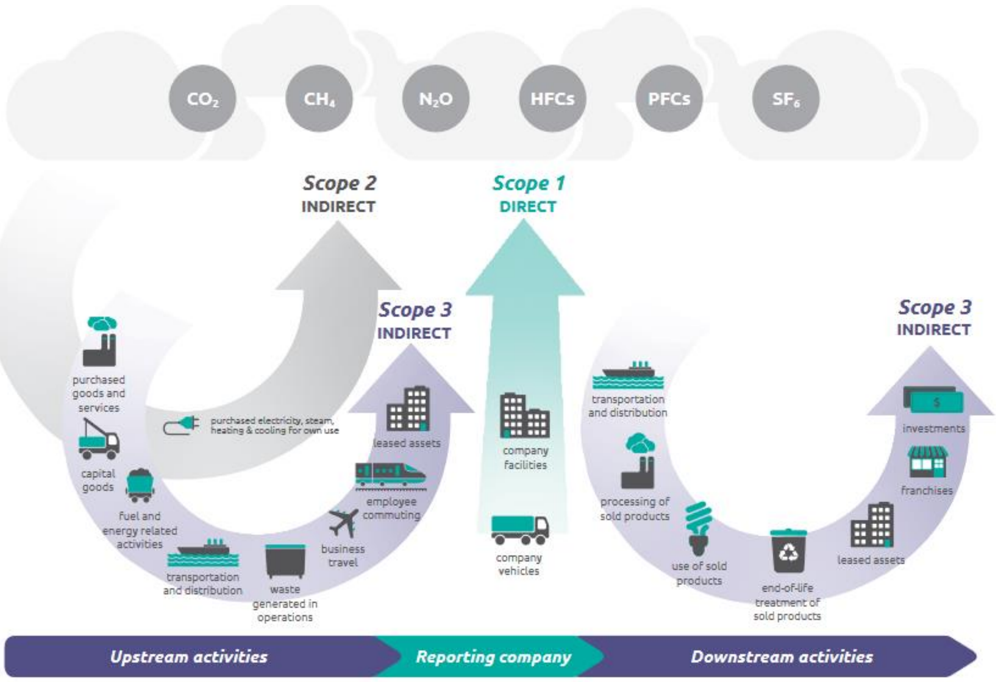

Figure 1: Overview of the assignment of emissions to scopes within a value chain

Source: (WRI und WBCSD 2011)

[1] Source TREMOD 6.43, WTW emissions for the year 2019 for road, air, inland waterways, and rail, air traffic excluding non-CO_2 effects, equivalence factor according to IPCC AR5.

2.3.3 Emission Calculation / Accounting of Projects

PCAF distinguishes three different approaches to calculating project emissions depending on the availability of project-specific data:

- Emissions reported by the project operator, which can be verified[1] or unverified[2] and were collected either directly by the operator or indirectly by an independent third party.
- Emission calculation based on collected physical activity data and associated emission factors (e.g., energy consumption in kWh/year and GHG emissions per kWh).
- Emission calculation based on collected economic activity data and official statistical data (e.g., revenue and average emission factors per euro of revenue).

According to PCAF, the first option provides the best data quality, while the third option offers the lowest data quality.

The financed emissions reported by the financial institution do not necessarily correspond to the total project emissions but may only represent a portion of them. According to (PCAF 2022), the financed emissions in the two relevant asset classes are calculated as follows:

For "project finance":

$$Financed\ emissions = Attribution\ factor \cdot Project\ emissions \qquad \text{(I)}$$

For "motor vehicle loans":

$$Financed\ emissions = Attribution\ factor \cdot Vehicle\ emissions \qquad \text{(II)}$$

The methodology for deriving the aforementioned attribution factor is explained in Section 2.5.1. For vehicle emissions, the methodology recommended by PCAF corresponds to the methodology already used by KfW FC:

$$Vehicle\ emissions = Mileage \cdot Consumption \cdot Emission\ factor \qquad \text{(III)}$$

This approach is based on physical activity data (ASIF method) and thus follows the aforementioned second PCAF approach for calculating project emissions.

[1] confirmed by an external auditor
[2] without external auditor

2.4 Calculation of Relative Emissions

2.4.1 General Approach

The various methodologies use the same principle to calculate the relative emissions of financed projects: The relative emissions are determined from the difference between a project scenario (shown in blue in Figure 2) and a baseline or business-as-usual (BAU) scenario, which represents the "without project" emissions (shown in gray in Figure 2).

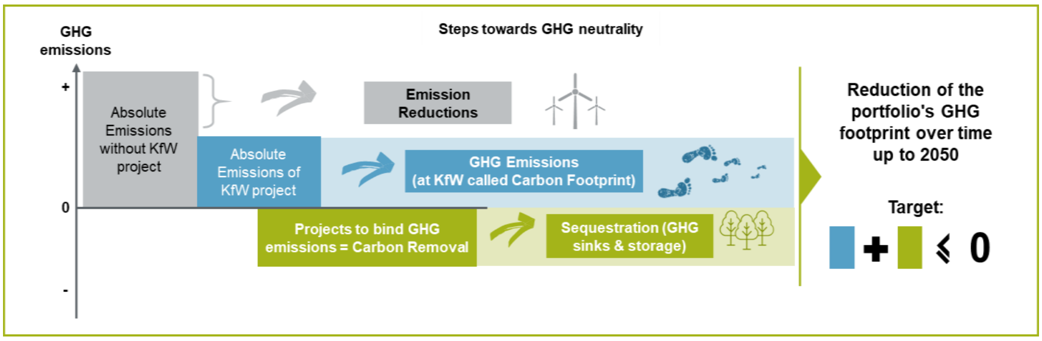

Figure 2: Fundamentals of the calculation of relative emissions at KfW FC

Source: (KfW Competence Centre Climate and Energy 2022)

According to (KfW Competence Centre Climate and Energy 2022), the BAU scenario represents the hypothetical scenario in which the KfW project is not implemented, but which meets the technical demand. For example, if KfW finances the procurement of new buses to meet the transportation needs of people, the BAU scenario should also address that demand. Therefore, the BAU scenario aims to answer the following question: How would passengers move if there were no new buses financed by KfW?

(KfW Competence Centre Climate and Energy 2022) requires that the BAU scenario meets three conditions: it has to be credible from a socioeconomic perspective, legally permissible, and must not rely on the continued use of facilities, vehicles, etc., beyond the end of their lifetime. According to (IFI TWG 2015), the BAU scenario should be dynamic[1] and based on the same methodology as the project scenario.

There are different approaches in the literature for designing the BAU scenario that meet the aforementioned framework conditions but lead to different results. Table 1 compares the PCAF and IFI TWG guidelines in this regard. If multiple BAU scenarios appear feasible, the most conservative one (i.e., the BAU scenario with the lowest emissions) should be chosen (IFI TWG 2021).

[1] The BAU scenario can be designed as either dynamic or static. Static emission factors do not change over time, while dynamic emission factors are time-dependent (Greenhalgh et al. 2005). For example, in the BAU scenario, the current emission factors can be consistently used, or they can be modeled based on the projected future development of the vehicle fleet.

Table 1: Methodological differences between PCAF and IFI TWG regarding the BAU scenario

	PCAF	IFI TWG
Baseline Determination	Previous GHG profile of energy generation (corresponds to Option 3 according to IFI TWG)	1. Forward-looking baseline (implementation of other alternative technologies, projects) 2. Average market performance (the market will meet demand without the investment) 3. Current state, previous GHG profile; recommended for renovation measures and land use changes
In any case: If multiple alternative outcomes are available, the more conservative one should be chosen.		

Source: (Guidehouse 2023)

2.4.2 System Boundary

The scope system (scopes 1, 2 and 3) from emissions accounting (Chapter 2.3) is not relevant for relative emissions. These are reported separately from absolute emissions and without the use of scopes. Nevertheless, the boundaries of the emissions to be considered have to be established, i.e., whether, for example, the upstream emissions of the energy consumed in the project (e.g., emissions from electricity production) should be included.

In a complete life cycle analysis of a product (e.g., passenger car), emissions arising from the production and use of that product are considered, as well as additional emissions along the value chain, such as emissions resulting from the manufacture of machine tools (e.g., milling machines used in car production). In projects aimed at reducing greenhouse gases, these secondary emissions can be relevant, and their accounting may be desirable; however, the collection and provision of the necessary data pose a significant barrier that could jeopardize the implementation of projects (Greenhalgh et al. 2005).

In (Greenhalgh et al. 2005), the impact of a project is divided into primary and secondary effects. A primary effect is the intended change in greenhouse gas emissions resulting from a project activity. A secondary effect is an unintended change in greenhouse gas emissions caused by a project activity. Secondary effects are distinguished between:

- One-time impacts, i.e., changes in GHG emissions related to the construction, installation, and commissioning or decommissioning and completion of the project activity, including upstream and downstream effects, and
- Recurring impacts of GHG emissions associated with the inputs of the project activity (upstream) or with the products of the project activity (downstream).

Under the GHG Protocol, only significant secondary effects need to be monitored and quantified. Primary and significant secondary effects are taken into account in GHG quantification, regardless of whether they occur outside the direct control of the project managers or at GHG sources/sinks that are owned or controlled by the project participants.

The system boundary, i.e., the scope of the emissions considered, has to be clearly defined so that all relevant emissions are accounted for with sufficient accuracy and reasonable effort. However, a differentiated accounting of relative emissions along the value chain or by primary and secondary effects is not necessary.

According to (KfW Competence Centre Climate and Energy 2022), the accounting boundaries should also include emissions associated with the construction of infrastructure and vehicles, provided they are significant (e.g., in the case of subway construction). Potential rebound effects[1] are not explicitly/separately considered in the GHG methodology, but they should be part of project planning.

2.4.3 Calculation Methodology for Transportation Projects

The literature is significantly less extensive and detailed regarding the calculation of relative emissions compared to absolute emissions. In this section, we summarize the key points that could be derived from the literature.

The basic calculation described in Section 2.4.1 is presented in Equation IV:

$$R = \sum_{i=0}^{T}(P_i - B_i) \qquad \text{(IV)}$$

where

R	-	Total relative emissions [t CO_{2eq}]
P_i	-	Emissions in the project scenario in year i [t CO_{2eq}]
B_i	-	Emissions in the BAU scenario in year i [t CO_{2eq}]
i	-	Year
T	-	Project lifetime

Negative relative emissions in Equation IV correspond to an emission reduction.

In the transportation sector, the effects of a project are typically captured by the ASI structure: avoid – shift – improve. Avoidance and shifting effects arise from a changed travel pattern. For example, new local shopping opportunities or the introduction of a toll can shorten or eliminate trips (traffic avoidance). New buses, in turn, can enhance the attractiveness of public transport, leading to shifts from more environmentally harmful modes of transport. The promotion of projects aimed at more environmentally friendly propulsion, such as electric buses instead of diesel buses, represents an improvement. The three mentioned "levers" are illustrated in Figure 3.

[1] The increase in energy consumption resulting from an energy efficiency measure is referred to as a rebound effect. This is often triggered by an undesirable change in behavior, for example, when the purchase of a new electric vehicle leads to higher mileage because the operating costs are lower than those of a fossil-fueled vehicle. This increases energy consumption and potentially negates the intended GHG reduction.

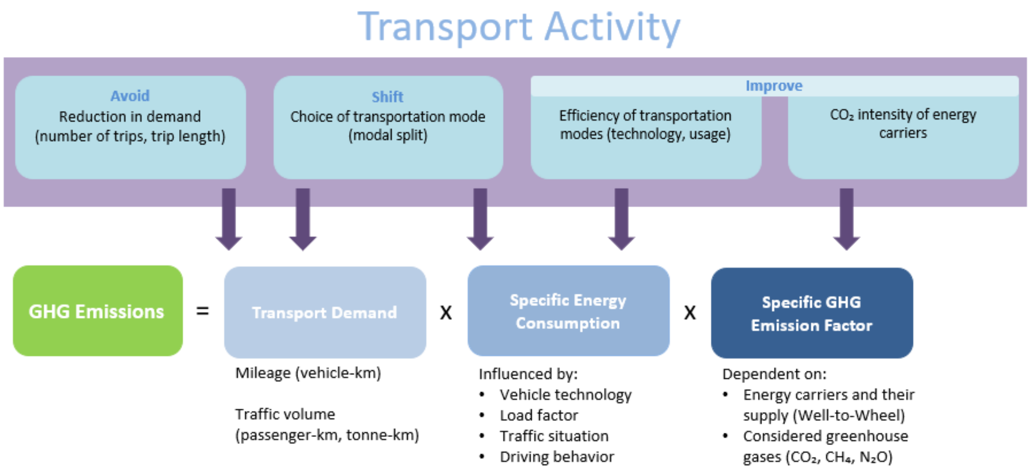

Figure 3: Levers for emission reduction in the transport sector

2.4.4 Determining the Impact of a Project: The Concept of Additionality

The challenge with many projects is that they often would have been implemented regardless of financial support. For example, stricter environmental regulations may lead to mandatory project implementations, or projects may be carried out out of self-interest due to rising energy prices. In relation to historical GHG emissions, the implementation of the financed project would indeed result in GHG reductions, but compared to an alternative scenario without financial assistance, the relative emissions in this example would be zero. In these cases, it is merely a matter of deadweight effects, and therefore the lender should not claim any emission reductions (Greenhalgh et al. 2005).

If the change in emissions is causally linked to the financial support, then the measure meets the principle of "additionality". Determining whether additionality exists can be challenging. (Greenhalgh et al. 2005) recommends the testing procedures described in Figure 4 for this purpose.

TABLE 3.1 Examples of possible "tests" for additionality

TEST	GENERAL DESCRIPTION OF THE TEST AS IT IS COMMONLY FORMULATED
Legal, Regulatory, or Institutional Test	The GHG project must reduce GHG emissions below the level required (or effectively required) by any official policies, regulations, guidance, or industry standards. If these reductions are not achieved, the assumption is that the only real reason for doing the project is to comply with regulations, and any claimed GHG reductions are not additional.
Technology Test	The GHG project and its associated GHG reductions are considered additional if the GHG project involves a technology that is not likely to be employed for reasons other than reducing GHG emissions. The default assumption is that for these technologies, GHG reductions are a decisive reason (if not the only reason) for implementing them. GHG projects involving other technologies could still be considered additional, but must demonstrate additionality through some other means.
Investment Test	Under the most common version of this test, a GHG project is assumed to be additional if it can be demonstrated (e.g., through the divulgence of project financial data) that it would have a low rate of return without revenue from GHG reductions. The underlying assumption is that GHG reductions must be a decisive reason for implementing a project that is not an attractive investment in the absence of any revenue associated with its GHG reductions. A GHG project with a high or competitive rate of return could still be additional, but must demonstrate additionality through some other means.
Common Practice Test	The GHG project must reduce GHG emissions below levels produced by "common practice" technologies that produce the same products and services as the GHG project. If it does not, the assumption is that GHG reductions are not a decisive reason for pursuing the project (or conversely, that the only real reason is to conform to common practice for the same reasons as other actors in the same market). Therefore, the GHG project is not considered to be additional.
Timing Test	The GHG project must have been initiated after a certain date to be considered additional. The implicit assumption is that any project started before the required date (e.g., before the start of a GHG program) could not have been motivated by GHG reductions. Under most versions of this test, though, GHG projects started after the required date must still further establish additionality through some other test.

Figure 4: Examples for testing the additionality of a project

Source: (Greenhalgh et al. 2005)

Furthermore, an assessment of additionality occurs somewhat automatically when a dynamic, forward-looking BAU scenario is used in the calculation of relative GHG emissions, as recommended by the IFI (see Chapter 2.4.1).

2.4.5 Examples for Defining BAU Scenarios

As outlined in Section 2.4.1, multiple BAU scenarios can typically be constructed for a project, meaning a decision has to be made for a specific BAU scenario. Below are some examples that illustrate the choices different banks have made in this regard. It is important to note that according to IFI guidelines, the most conservative BAU scenario should be selected when there is a choice between different BAU scenarios (i.e., baseline emissions should tend to be underestimated). Unfortunately, reports often do not clarify how the BAU scenarios were specifically designed, even though certain "details" can significantly influence the resulting relative emissions.

KfW

KfW uses a purely conventional (fossil + nuclear) BAU scenario in the field of renewable energies[1] (Bickel et al. 2021), which is based on the publication "Emissions Accounting of Renewable Energy Sources" from the German Federal Environmental Agency (Lauf et al. 2022).

In the KfW funding programs "Energy-Efficient Construction and Renovation" for residential buildings, the following BAU scenarios are used:

- New construction: comparable new construction according to legal minimum requirements
- Renovation: the same building in its pre-renovation state (Heinrich et al. 2022)

In principle, the determination of relative emissions in different sectors follows different logics, so a cross-sector comparison of BAU scenarios does not always make sense.

Transport Sector

In the transport sector, for example, the Finnish Municipality Finance PLC uses a newly registered vehicle that meets the EU fleet limit (i. e., emits 95 g CO_2/km) in the BAU scenario for financing battery-electric passenger cars and light commercial vehicles. For public transport projects, project-specific analyses are conducted, but the details are unfortunately not presented in the report (MuniFin 2023).

The Norwegian municipal bank KBN uses a new diesel vehicle that emits 126 g CO_2/km in the BAU scenario for battery-electric passenger cars (KBN 2023).

The Stockholm region states in its Impact Report that it assumes 50% of trips for a train project will be made by car in the BAU scenario, with the car emitting 190 g CO_{2e}/km (Region Stockholm n.d.).

The Swiss Eurofima finances trains, including additional electric trains, replacements for electric trains, and modernizations of electric trains. In all these cases, the BAU scenario consists of 100% car trips, with cars emitting 290 g CO_2/km (according to Eurofima, an average car from the European fleet) (Eurofima 2022). In other words, Eurofima assumes that all passengers of a newly purchased or even just modernized train would use a car (with high emissions) without this measure.

While the previously mentioned approaches in the transportation sector generally seem to align with various guidelines, we consider the design of the BAU scenario in the case of Eurofima to be overly optimistic, especially when taking into account the principle that a BAU scenario should be designed conservatively in case of doubt.

[1] This contradicts the methodology paper prepared by Guidehouse on behalf of the KfW Bank Group. There, the so-called Combined Margin is specified as the BAU scenario for renewable energy projects (Guidehouse 2023).

2.5 Temporal Aspects and Attribution Factor

2.5.1 Attribution Factor

If multiple lenders (several financial institutions, equity from the borrower, etc.) are involved in the financing of a project, the absolute or relative emissions of the project have to be allocated among the lenders to avoid double counting. For this purpose, the so-called attribution factor is used, which is described in this chapter. Theoretical principles can be found in the literature particularly with regard to absolute emissions, which is why this case is dealt with first.

In theory, the double counting of absolute emissions between co-financing institutions and between transactions within the same asset class of a financial institution should be avoided through the consistent application of the attribution factor defined by PCAF (PCAF 2022). However, double counting can occur when a financial institution finances multiple companies within the same value chain. For example, the scope 1 emissions of a utility company that supplies electricity to a business would be part of scope 2 in that business's inventory. If both companies are financed by the same financial institution, these emissions would be counted twice in its inventory. Unfortunately, this form of double counting cannot be avoided according to (PCAF 2022).

(PCAF 2022) recommends the following approach for attributing emissions: The absolute emissions from outstanding loans should be recorded annually by the financial institutions. The portion attributed to the financial institution is determined by the attribution factor, which is given by the ratio between the outstanding loan amount[1] (numerator, the amount of credit provided by the financier) and the total capital of the project (denominator), i.e.

$$Attribution\ factor_i = \frac{outstanding\ investment_i}{Total\ equity + debt} \qquad \text{(V)}$$

where

i - Year

According to (PCAF 2022), it is expected that the attribution factor for „project finance“ is dynamic, meaning that the projects report annually on their finances, including balance sheet information (i.e. the total equity and outstanding debts of the project). The development of equity and debt is illustrated in Figure 5 as an example.

[1] Interest should not be included in the amount.

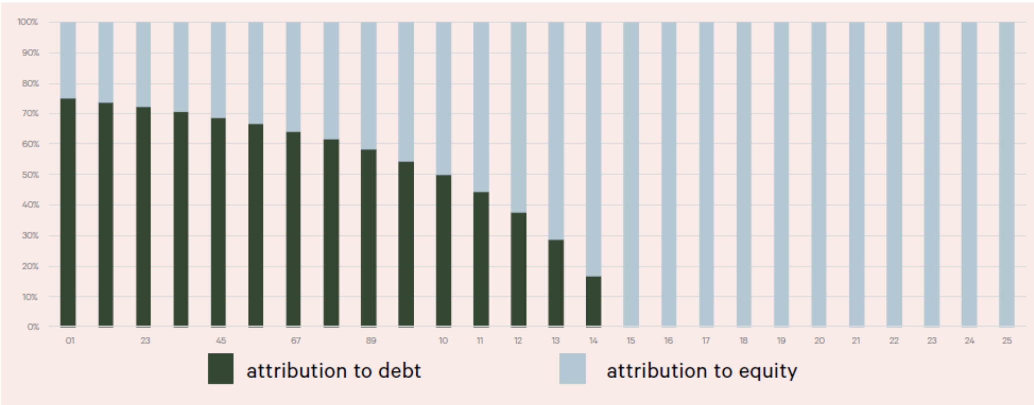

Figure 5: Example of changes in the attribution to equity and debt over time

Source: (PCAF 2022)

If the calculation of the attribution factor is not possible due to insufficient information, the attribution factor can be estimated. The PCAF standard leaves it to the financial institution to determine the best way to estimate the attribution factor, but it mentions that the estimates should be based on region- and sector-specific average financial data. If no suitable estimates are available or if the emissions are negligible, the attribution factor should be set to 0.

The GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard proposes a similar but simpler method for accounting for GHG emissions from loans and investments. The total emissions of a project are allocated based on the amount of the loan or investment.

KfW FC (KfW Competence Centre Climate and Energy 2022) follows an approach in line with (EIB 2023), which is to relate the attribution factor to the total project financing at the start of the project, i.e. if KfW FC signs a financing contract for 25% of the total investment of a project, then 25% of the total estimated project emissions are attributed to KfW.

According to (Guidehouse 2023), the individual reductions are weighted with an attribution factor that corresponds to the financing share in the project. The attribution factor has a value between 0 and 1. The methodology applies to both absolute and relative emissions.

When attributing relative emissions, there are two additional challenges compared to attributing absolute emissions. On one hand, the fundamental principle of conservativeness states that absolute emissions should tend to be overestimated, while relative emissions should tend to be underestimated. Thus, double counting of relative emissions poses a significantly greater problem than double counting of absolute emissions. On the other hand, when calculating relative emissions, the entire system should always be considered, as relative emissions may otherwise not be meaningfully determined. For example, financing rail infrastructure without the associated vehicles does not lead to emission reductions, and vice versa. If only vehicles or only infrastructure are financed, an additional attribution factor would need to be applied to allocate the relative emissions between vehicles and infrastructure to avoid double counting.

This issue has not been recognized in the literature available to us, which is why there are no recommendations on this matter. The particular challenge in determining such a second attribution factor is that infrastructure and vehicles are often not acquired simultaneously, and therefore, there is usually no information available about the other component.

2.5.2 Lifetime and Annual Reporting

According to (PCAF 2022), financial institutions should set a fixed date as the basis for emissions reporting to determine their loan and investment positions, such as the last day of their fiscal year (e.g., June 30 or December 31). The greenhouse gas accounting period has to align with the financial accounting period. In contrast, (WRI und WBCSD, 2013) report emissions over the entire project lifetime in the initial year, i.e., the year of the loan issuance. In subsequent years, no emissions from the project are reported. KfW follows a similar approach: In the context of impact reporting (KfW 2023) the issued loans are only considered in the year of allocation, but the relative emissions for the entire lifespan are reported in that year.

According to (KfW Competence Centre Climate and Energy 2022), the lifetime of the project determines the period for which absolute and relative emissions should be calculated. A standard lifetime of 20 years is specified. In the transport sector, the lifetime is to be selected on a case-by-case basis by the person conducting the quantification. The annual GHG emissions are determined by dividing the total emissions of the project (emissions from the construction and operational phases) by the lifetime of the project.

2.6 Electricity Emission Factors

To determine the GHG emissions from electricity usage, corresponding emission factors are necessary. There are several approaches to calculating these electricity emission factors, which are presented below. It is important to distinguish between electricity-producing projects (e.g., construction of wind turbines) and electricity-consuming projects. In the transport sector, only the latter are relevant.

For renewable energy projects, (PCAF 2022) recommends using the Operating Margin emission factor[1] for accounting for avoided emissions (see Figure 6). In principle, PCAF advises excluding nuclear energy in line with the IFI methodology, but it also allows for the inclusion of nuclear energy, as most data sources incorporate nuclear energy into the mix of fossil fuels.

[1] The Operating Margin corresponds to the existing power plants whose operation is influenced by the project (IFI 2021).

Table 5-11. Emission factors per type of power mix

Preferred options	Type of mix	Description of emission factors
1	Operating margin[132]	The operating margin, represents the marginal generating capacity in the existing dispatch hierarchy in a country/region that will most likely be displaced (i.e., the generation from the power plants with the highest variable operating costs in the economic merit order dispatch of the electricity system).
2	Fossil fuel mix traded	Emission factors based on the emissions of all fossil fuel power (including or excluding nuclear) traded (i.e., produced and imported minus exported) in a country or region.
3	Fossil fuel mix produced	Emission factors based on the emissions of all fossil fuel power (including or excluding nuclear) produced in a country or region.
4	Average electricity mix	Emission factors based on the emissions of all power (fossil and non-fossil) produced in a country or region.

Figure 6: Electricity emission factor for determing GHG reductions from renewable energy projects

Source: (PCAF 2022)

For projects that consume energy (such as in the transport sector), the PCAF recommends using the emission factor of the average electricity mix. If possible, this should refer to the local or regional electricity mix at the borrower's location, or, if not available, at the location of the branch of the financial institution that granted the loan. If this is also not available, it is recommended to use the emission factor of the average national electricity mix (PCAF 2022).

The IFI method determines the absolute and relative emissions from electricity-consuming projects using the emission factor of the so-called Combined Margin, which is a mix of 33% Operating Margin and 67% Build Margin, taking into account the transformation of the electricity grid (IFI TWG 2020). The IFI provides electricity emission factors for many countries worldwide that follow this methodology (IFI 2021).

3 Methodology for Calculating the Reduction of GHG and Air Pollutant Emissions in the Transport Sector through KfW Financing

In the following chapter, the methodology developed based on the methodologies and guidelines presented in Chapter 2 for calculating the reduction of GHG and air pollutant emissions in the transport sector through KfW financing will be outlined. First, the system boundary and the general approach to accounting for Clean Transport projects will be described. This will be followed by a description of the design of project and business-as-usual scenarios. Section 3.4 addresses the origin of the various emission factors used. The chapter concludes with discussions on the lifetime of the projects and the attribution factor, i.e., it explains how the emissions are allocated proportionally to KfW financing.

The methodology for assessing the ecological impacts of financing activities is a relatively new field that KfW is working on in parallel across several projects, which are at different stages of progress. The decisions and assumptions made here are coordinated with the other projects and sectors, but there is the possibility of changing them if, at a later point, a different solution appears to be more appropriate in the overall view.

3.1 System Boundary

Fundamental to the emission calculation is the definition of the accounting boundaries.

The greenhouse gases CO_2, CH_4 (methane), and N_2O (nitrous oxide) are taken into account. They are summarized as CO_2 equivalents using the equivalence factors according to IPCC AR5 (IPCC 2013). In addition, the most important air pollutants for the transport sector, namely NO_x (nitrogen oxides), CO (carbon monoxide), PM (particulate matter), and NMVOC (non-methane volatile organic compounds), are also considered.

In the present methodology, we depart from the scope logic of the GHG Protocol. On the one hand, the classification into scopes is not necessary, as only relative and not absolute emissions are calculated. On the other hand, different delimitations are more useful in the transport sector. The following impact chain sections are usually considered:

- Tank-to-Wheel (TTW): Direct emissions that arise from the operation of the vehicles. Only exhaust emissions are included. Particle emissions from break and tyre wear are not taken into account.
- Well-to-Tank (WTT): Upstream emissions. These include the extraction and processing of primary energy as well as the distribution of energy to the vehicles (including distribution losses). In the case of overhead line or battery-electric vehicles, these are the emissions from electricity generation, including upstream and distribution.

- Vehicles and infrastructure: Emissions arising from the provision and manufacturing of vehicles (MAT) and infrastructure (INFRA). These include the extraction, processing, and transportation of raw materials, the use of construction machinery (NRMM: non-road mobile machinery), the manufacturing and maintenance of vehicles and infrastructure, as well as the disposal and recycling of raw materials at the end of their lifecycle. The GHG emissions from maintenance and end-of-life processes are usually negligible[1] and are therefore generally not considered. An exception is made for sources such as (Allekotte et al. 2020), which report MAT and INFRA emissions including maintenance and end-of-life processes.

The GHG emissions are calculated taking into account the three aforementioned sections of impact chains. In contrast, the air pollutant emissions are only calculated for the TTW (Tank-to-Wheel) section. This is because, unlike greenhouse gases, the location of the release is relevant for air pollutants. Since damage from pollutants occurs particularly close to traffic (TTW), while factories (MAT), refineries, and power plants (WTT) tend to be located further away from residential areas, only the TTW emissions are considered here.

3.2 Calculation of the Relative Emissions of KfW Projects

To determine the reduction of GHG and air pollutant emissions through KfW financing as part of the impact reporting, the relative emissions of the financed individual projects have to be calculated. It is important to note that this calculation does not represent an emissions footprint or inventory, but rather a calculation of emission reductions.

As outlined in Chapter 2.4, the relative emissions result from the difference between the absolute emissions in the project scenario and in the BAU scenario. The project scenario represents the state that is expected to occur as a result of the realization of the project financed by KfW. It thus corresponds to the likely future. In contrast, the BAU scenario represents a hypothetical state in which the financing of the project does not take place. The definition of the scenarios (project and BAU scenario) is described in Section 3.3. Since KfW is generally only allocated a portion of the relative emissions of a project, an attribution factor (Section 3.6) has to be taken into account. Equation VI shows the reductions that can be attributed to KfW. The relative emissions are calculated for KfW's impact reports over the entire lifetime (Section 3.5) of the project object and are fully reported in the year of loan disbursement.

$$Rel.Emissions_{KfW} = Attribution\ Factor \cdot Rel.Emissions_{Project}$$

$$= Attribution\ Factor \cdot \left(Abs.Em._{Project} - Abs.Em._{BAU}\right) \qquad \text{(VI)}$$

where

Rel.Emissions	-	Relative Emissions from Project Implementation [t]
Attribution Factor	-	Proportion of relative emissions that can be attributed to KfW [%]

[1] In the case of conventional and battery-electric cars, end-of-life processes account for approximately 2 to 4 percent of the total lifecycle GHG emissions (Kämper et al. 2020).

Abs.Em. - Absolute Emissions in the scenario over the entire lifetime [t]

Project - Project Scenario

BAU - Business-as-usual Scenario

The calculation of absolute emissions in the scenarios is carried out according to the second approach of the PCAF, see Section 2.3.3. It is conducted ex-ante and is based on data that has to be collected in the project context or during the approval process of the specific loan. The advantage of this approach is that, unlike a direct input of emission reductions by the applicant (approach 1 according to PCAF), it creates transparency and consistency. Although collecting the data involves additional effort, it is expected to enhance the accuracy of the calculations, particularly compared to approach 3 according to PCAF (calculation based on economic activity). The data that applicants have to provide for each project is explained in Chapter 4. Additionally, default values for projects in Germany are provided by TREMOD, which will be used for the calculations and do not need to be entered by the applicant, see Section 3.4.

The absolute emissions in the scenarios are generally derived from activity data multiplied by emission factors (see Equation VII). This is in line with the approach of KfW FC in the transport sector.

$$Abs.Em. = T \cdot Activity \cdot EF \qquad \text{(VII)}$$

where

Abs.Em. - Absolute Emissions over the entire lifetime [t]

T - Lifetime of the vehicle or infrastructure [years]

Activity - Annual activity rate of the vehicles or infrastructure

EF - Emission factor per activity

Additionally, if relevant, the emissions that arise from the construction of infrastructure or vehicles are included.

For example, the GHG emissions of vehicles are calculated according to Equation VIII. This corresponds to the methodology recommended by the PCAF and used by KfW FC. In this example, the activity is derived from the number of vehicles and the average annual mileage per vehicle. The emission factor per activity is obtained by multiplying the specific consumption of the vehicles by the fuel-specific emission factor.

$$Abs.Em. = T \cdot (N \cdot M) \cdot (Consumption_{Vhl} \cdot EF_K) + N \cdot EF_{production} \qquad \text{(VIII)}$$

where

Abs.Em. - Absolute emissions of vehicles over their lifetime [t]

T - Vehicle lifetime [a]

N	-	Number of Vehicles
M	-	Annual Mileage per Vehicle [km/a]
Consumption	-	Consumption per vehicle kilometre [MJ/km]
EF	-	Emission factor of the fuel used in the vehicle [g/MJ]
$EF_{production}$	-	Emission factor for vehicle production (g/veh)

In the case of infrastructures, on the one hand, the infrastructure itself is considered. The INFRA emissions for roads, railways, etc., are typically calculated based on the length and emissions per kilometer. On the other hand, the vehicles that operate on or are supplied with energy by the infrastructure are accounted for as described above.

Therefore, the determination of lifetime, activity, dimensions of the infrastructure, and emission factors is a prerequisite for calculating both absolute and relative emissions. The following sections describe the assumptions for these aspects as well as the attribution factor.

3.3 Basic Assumptions for Defining the Scenarios

As explained in Chapter 2.4, various approaches can be considered for defining the BAU scenario (see Table 1). Table 2 presents the options discussed with KfW that are relevant for the BAU scenario, using the example of financing an electric vehicle.

In close collaboration with KfW, Option 4 was selected. This corresponds to a forward-looking baseline and is similar to KfW's approach for renewable energy projects (Guidehouse 2023), for which IFI TWG emission factors are used, taking into account both the impacts of the financed project on the current and future electricity mix. Furthermore, Option 4 includes a mix of several possible alternatives to purchasing a new vehicle: continuing to operate the existing car (older existing vehicles), purchasing a combustion or electric vehicle now (new registrations in 2022), or at a later date (new registrations in subsequent years). The emission factors for infrastructure and vehicle manufacturing are kept constant, unlike those for vehicle consumption, as there is limited scientific knowledge regarding the future development of these emission factors. Among the options listed in Table 2, BAU scenarios 1b and 4 represent the most conservative options. Thus, the decision for Option 4 follows the guidelines described in Chapter 2.4, which call for the selection of a conservative BAU scenario.

Table 2: Possible options for defining the BAU scenario using the example of financing an electric vehicle

	Project scenario	BAU scenario Option 1a	BAU scenario Option 1b	BAU scenario Option 2	BAU scenario Option 3	BAU scenario Option 4
Vehicle type	car	car	car	car	car	car
Vehicle age	new vehicle	new vehicle	new vehicle	existing vehicle	⌀ German car fleet 2022	⌀ German car fleet 2022-2037[1]
Drive type	battery electric (BEV)	drive with most new registrations in 2022 (i.e., gasoline engine)	mix of drives according to new registration numbers 2022 (including BEV share)	previous drive	most common drive in the German vehicle fleet 2022 (i.e., gasoline engine)	mix of drives in the German fleet 2022-2037 (including BEV share)
Energy consumption	⌀ new BEV cars	⌀ new cars with above drive	⌀ new cars[2]	consumption of the existing car	⌀ fleet 2022, cars with above drive	⌀ car fleet 2022-2037, mix of drives[3]
Mileage	mileage identical to BAU (Assumption: unchanged vehicle usage)	⌀ cars with above drive	⌀ car fleet	mileage of the existing car	⌀ cars with above drive	⌀ car fleet
Lifetime	⌀ lifetime of the car fleet					

[1] The average lifetime of a car is 16 years, so a car purchased at the beginning of 2022 is expected to be used until the end of 2037. Therefore, the average of the vehicle fleet is considered over the entire lifetime of the car.
[2] Emissions are calculated for each drive type based on energy consumption and then weighted according to the new registration numbers of the respective drive type.
[3] Emissions are calculated for each drive type based on energy consumption and then weighted according to the stock of the respective drive type in each year.

The design of the project and BAU scenarios for transport projects is described in detail in the following section. A distinction is made between vehicle-oriented projects and infrastructure projects, as the fundamental assumptions differ significantly between the two project types.

Vehicle-Oriented Projects

In the **project scenario** for vehicle-oriented projects, a new vehicle is considered. This vehicle has the drive technology chosen by the borrower and otherwise corresponds to the average new vehicle of the vehicle type concerned (e.g., car, city bus, tractor-trailer, etc.).

A project only leads to emission reductions if it is additional, meaning that the corresponding project implementation would not have occurred without the financing (see Section 2.4.4). This is reflected in the **BAU scenario**. Additionality is only present if the BAU scenario and the project scenario differ. In vehicle-oriented projects, the difference often lies in the drive technology. This is based on the assumption that, even without the financing, a vehicle would have been operated to the same extent (same activity, i.e., same mileage), as investment barriers or liquidity issues are generally considered to be less significant for vehicles than for infrastructures, which are often associated with higher costs. Furthermore, mobility needs and demand, especially for freight transport, are a significant factor in the purchasing decision for a vehicle to meet that demand. Financing, on the other hand, leads to an increased acquisition of more environmentally friendly vehicles, as it reduces the barrier of higher investment costs for alternatives compared to conventional drives. In the area of public transport and active mobility, additionally acquired vehicles can lead to a shift away from individual motorised transport (IMT). To determine whether a modal shift is considered, i.e., whether the BAU scenario includes IMT trips, it has to be assessed in these cases whether the new vehicles are replacement or additional vehicles.

As a reference vehicle, a generic vehicle from the fleet averaged over the lifetime of the acquired vehicle is used in the BAU scenario (see Table 2, Option 4). Accordingly, the financed vehicle partially replaces a diesel vehicle, but also partially replaces an electric vehicle, etc. When promoting environmentally friendly drives, deadweight effects may occur. Whether an electric car would have been purchased without financing cannot be definitively determined, but the potential deadweight effect is partially accounted for by not considering a purely combustion engine vehicle as the comparison vehicle in the BAU scenario, but rather a generic vehicle that consists partly of electric vehicles. The representation of an alternative reality is always subject to a certain degree of uncertainty, which we aim to reduce as much as possible with this methodology.

Contrary to the procedure described so far, in three cases no alternative theoretical vehicle is considered in the BAU scenario:

- If the project replaces a metro/tram/train with a new metro/tram/tram, there is no additionality as the newly acquired vehicle would have been electric even without the loan. The project and BAU scenarios are therefore identical and the relative emissions are zero.
- In the case of ship modernisations, the state before and after the modernisation is compared.
- If charging infrastructure for ships is financed, a new ship is used in the BAU scenario instead of the average future ship due to the low availability of data.

In vehicle-oriented projects with a change in drive technology, it is assumed that the MAT emissions of the baseline vehicle (i.e., without energy storage and fuel cell) are independent of the drive type and thus irrelevant for the relative GHG emissions. Therefore, in this case, only the GHG emissions from the production of the battery, fuel cell, and hydrogen tank are considered. If a modal shift occurs, different vehicle types are used in the project and BAU scenarios, necessitating the inclusion of the MAT emissions of the baseline vehicle. In the case of a change in drive technology, the MAT emissions of the batteries from electric vehicles are also considered in the BAU scenario, while this is not done in the case of a modal shift for reasons of complexity and relevance.

The following example is intended to clarify the definition of the comparison vehicle in the BAU scenario in the case of a change in drive technology: KfW finances an electric car in 2022. The average lifetime mileage of a car in Germany is 220,000 km with an average lifetime of 16 years. Over the lifetime of the car, from 2022 to 2037, the average vehicle of the German car fleet is determined for each year (i.e., technology shares and consumption). The reference vehicle used in the BAU scenario corresponds to the arithmetic mean of the 16 average vehicles in the observation period from 2022 to 2037. The reference car consumes 1.00 MJ gasoline/km, 0.76 MJ diesel/km, 0.003 MJ natural gas/km, 0.01 MJ LPG/km, and 0.22 MJ electricity/km. In contrast, the financed vehicle (see project scenario) consumes 0.80 MJ electricity/km (value of a new BEV car in 2022). The consumptions can ultimately be multiplied by the fuel-specific emission factors to obtain the emission factor per mileage.

Infrastructure Projects

In the case of infrastructure projects, the **project scenario** includes the construction of the infrastructure and all other relevant emissions associated with it. This also includes the operation (primarily the power supply) and, if applicable, the manufacturing of the vehicles that utilize the infrastructure.

The **BAU scenario** represents the state without the financed infrastructure. It is assumed that this infrastructure would not have been built without the financing. Therefore, a modal shift typically occurs, meaning that in the BAU scenario, the transport performance provided on the financed infrastructure in the project scenario is largely delivered by other modes of transport. An exception is made for refueling and charging infrastructures, which are treated similarly to a change in drive technology in vehicle-related projects.

In the case of a modal shift, the transport performance in the BAU scenario is generally somewhat lower than in the project scenario, as it is assumed that the measure induces additional trips, as was observed with the 9-Euro-Ticket, for example (Grahl und Koch 2022). For projects with modal shift effects, borrowers should provide information on the modal shift shares. If they are unable to do so, corresponding assumptions will be made (see Chapter 4.1.1).

Since emissions per transport performance, i.e., per passenger kilometer (pkm), are relevant in the case of a modal shift, rather than emissions per vehicle kilometer, the occupancy rates of the vehicles have to be taken into account. For all displacement effects, the BAU scenario assumes average usage in the respective country. In the project scenario, this default value is overridden if the borrower provides this information. It should be noted that occupancy rates can vary significantly between different cities, and thus the emission factors per transport performance may deviate from the average. However, the effort required for data collection at this point would not be proportionate to the gain in accuracy.

In addition to the WTW emissions per transport performance, the emissions for the provision of alternative infrastructure have to be also considered in the BAU scenario. For example, if a financed railway line were not realized, either a new road would be constructed or there would be higher costs associated with the expansion and maintenance of existing roads. These emissions are accounted for in the BAU scenario on a flat-rate basis per transport performance.

3.4 Emission Factors

Emission factors are, like most model parameters, dynamic and should be updated over time.

The emission factors (e.g., direct CO_2 emissions of a car) are uniformly used across all projects. For the German context, they primarily come from TREMOD as well as other sources such as (Allekotte et al. 2020). For projects within the EU, all defaults can be derived from available official sources if quantification is required.

The following sections provide details on the emission factors for the various sections of impact chains. The example data presented here, valid for Germany, were derived as part of the quantification of the "Sustainable Mobility" loan program for the year 2022.

3.4.1 TTW: Direct Emissions of Vehicles

The emission factors for direct vehicle emissions (tank-to-wheel) are among the most important parameters in calculating emission reductions. The emission factors derived for Germany from the TREMOD database represent the average case for new or all vehicles per drive technology in Germany. This default data is used as a proxy for the actual consumption of the vehicles purchased thanks to KfW financing. Querying the individual consumption figures would be too time-consuming and error-prone. The average case includes not only the average size (standard consumptions) but also the average usage of the vehicles. This means that for all vehicles within a vehicle segment (e.g., cars, city buses, tractor-trailers, etc.), the same road shares (highway, rural roads, urban roads) and traffic situations (e.g., free flow, saturated, stop-and-go, etc.) are assumed. While this may vary in individual cases, such as when a KfW-financed vehicle is used exclusively for long distances and therefore has a higher highway share than the average vehicle, it remains true that using an average emission factor, considering the possibilities for data collection, represents the best possible approach. Resulting uncertainties, particularly concerning air pollutant emissions, must therefore be accepted. The more projects are considered, the more the uncertainties typically decrease.

Furthermore, TREMOD includes a trend scenario that takes future fleet development into account. It is used to derive the default values for future years (see values in Appendix 5.5). However, these values pertain only to Germany and reflect the most likely future development starting from the year 2023. Therefore, the use of these values is only advisable to a limited extent in an international context. However, due to the often higher market penetration of new efficient drive technologies in Germany, a conservative estimate of the relative emissions can generally be assumed when applying these values to international projects. For the TREMOD methodology, see the methodology report published by the UBA (Allekotte et al. 2023).

3.4.2 WTT: Emissions from Energy Provision

The TTW emissions described above are supplemented by the well-to-tank emissions (WTT, upstream emissions) for each energy carrier in order to obtain the well-to-wheel emissions (WTW) of the vehicles.

Fuels

Currently, and also in the coming years, the relevant liquid and gaseous fuels in road, rail, and inland waterway transport are gasoline, diesel, LPG, CNG, LNG, and hydrogen. With the exception of small biogenic shares, these are of fossil origin (hydrogen currently mainly comes from natural gas reforming). It is likely that hydrogen will first be gradually transitioned to a renewable source (so-called green hydrogen). This future development is included in the report (Biemann et al. 2024), from which the emission factors for hydrogen are derived (see Table 4). The emission factors for all other fuelds come from TREMOD 6.43.

The WTW emissions are derived from the WTT and TTW emissions, which are calculated for each vehicle category and each year, taking into account the corresponding energy carrier mix. The specific values used for the NaMo program 2022 can be found in Appendix 5.5.

Electricity

The production of electricity generates GHG emissions through the combustion of fossil energy carriers, the provision of these energy carriers, and the construction of power plants. These emissions are expected to decrease in the coming years due to an increasing share of renewable energy sources.

KfW has decided to use the electricity emission factors from the IFI TWG in the transport sector, as these are available for many countries and take into account the future development of the electricity mix by considering the Build Margin (see Chapter 2.6). However, the IFI TWG values have some weaknesses. On one hand, they do not include other greenhouse gases besides CO_2 or upstream emissions. On the other hand, the methodology for determining the emission factors has not been published, making it unclear, among other things, which time period the Build Margin specifically refers to. Furthermore, different lifetimes cannot be represented using the Combined Margin approach. For these reasons, KfW has also decided to allow other sources for electricity emission factors in the transport sector, provided they demonstrate higher quality. For Germany, the TREMOD trend scenario is therefore used, which provides electricity emission factors for each year up to 2050. This is based on real data from the Federal Environment Agency (Icha und Lauf n.d.) as well as scenarios created on behalf of the BMUV (Harthan et al. 2020) and the BMWK (BMWi 2017). It includes all relevant greehnhouse gases and considers the upstream chain of electricity generation. The underlying electricity mix is presented in Table 3. The share of renewable energies is expected to reach 60% by 2030 and 93% by 2050. Table 4 shows the resulting emission factors. In exceptional cases where electricity emission factors are needed for the period after 2050, the value for 2050 is extrapolated as a constant.

Table 3: Electricity generation in the TREMOD trend scenario

	2025	2030	2035	2050
Nuclear	0%	0%	0%	0%
Coal	27,7%	19,2%	9,6%	0%
Oil	0,4%	0,4%	0,4%	0,1%
Gas	15,3%	16,6%	15,8%	7,1%
Biomass	7,6%	7,0%	7,1%	5,4%
Water	3,6%	3,6%	3,7%	3,8%
Wind	30,4%	34,8%	41,8%	70,4%
Solar	10,5%	14,2%	17,3%	13,3%
Total Renewables	52%	60%	70%	93%

Source: TREMOD report (Allekotte et al. 2023)

Table 4: Electricity and hydrogen emission factors

Years	Electrcity EF [g CO_{2e}/kWh]	Hydrogen EF [g CO_{2e}/MJ]
2022	498	99
2025	446	99
2030	352	97
2035	234	87
2050	56	3

Sources: TREMOD 6.43 (Scenario), TREMOD 6.51 (2022) and (Biemann et al. 2024)

3.4.3 MAT & INFRA: Vehicle and Infrastructure Emissions

Vehicles

To determine the emissions from vehicle production, a vehicle is divided into the battery, fuel cell, and hydrogen tank on the one hand, and the baseline vehicle (all other vehicle components) on the other. It is assumed that the MAT emissions of the baseline vehicle are independent of the drive type. These emission factors are mostly sourced from **(Allekotte et al. 2020)** and are listed in Appendix 5.5. The calculation of the manufacturing emissions for the battery, fuel cell, and hydrogen tank is primarily based on emission factors from **(Biemann et al. 2024)**, which are presented in Table 5. These are multiplied by the battery capacity (or the power of the fuel cell or the capacity of the hydrogen tank) to obtain the GHG emissions.

Table 5: MAT emission factors for alternative drives

Category	GHG EF	Unit
GHG emissions battery	84	kg CO_{2eq}/kWh_{gross}
GHG emissions fuel cell	24	kg CO_{2eq}/kW
GHG emissions H_2 tank (gaseous)	204	kg CO_{2eq}/kg H_2
GHG emissions H_2 tank (liquid)	153	kg CO_{2eq}/kg H_2
Gross to net capacity factor	1,1	kWh_{gross}/kWh_{net}
H_2-liquefaction factor	1,3	kg H_2 liquid/kg H_2 gaseous

Sources: GHG EF battery, fuel cell, H_2 tank gaseous: (Biemann et al. 2024). GHG EF H_2 Tank liquid: own calculation. Gross-net factor: (Kramer et al. 2021). H_2-liquefaction factor: own estimate.

Infrastructure

Large infrastructure construction projects, such as rail transport projects, cause significant one-off GHG emissions. In contrast, the emissions for the construction of charging infrastructure are relatively low. A distinction is also made between new, reactivated and modernized rail lines. The main sources for deriving the defaults for the NaMo program 2022 are (Mottschall und Bergmann 2013) and (Allekotte et al. 2020). The values are provided in Appendix 5.5. In the BAU scenario, the infrastructure emissions are accounted for on a flat-rate basis per transport performance (in g/pkm) (Allekotte et al. 2020).

3.5 Lifetime

The lifetime of a financed project indicates the period over which the absolute or relative emissions should be considered. To calculate the annual relative emissions, the total relative emissions generated over the lifetime of the infrastructure or vehicles are divided by the respective lifetime. The lifetime is determined separately for each type of measure.

For simplicity, the analysis period begins at the start of the year of the (first) loan disbursement and ends upon reaching the lifetime. Inaccuracies may arise if the implementation of the project is delayed or if the construction of the infrastructure takes longer than one year. However, the error from this simplification is considered to be minor. Therefore, no further inquiry into the planned completion or implementation date is necessary. The analysis period is identical for both the project and BAU scenarios. It is assumed that the annual usage remains constant during the analysis period. In contrast, factors such as electricity and hydrogen emission factors (see Section 3.4.2) and the composition of the vehicle fleet in the BAU scenario may change during the analysis period.

Further use of the project object (infrastructure or vehicle) after the end of its lifetime is not taken into account. For example, the manufacturing emissions of an electric car are fully allocated to the usage period in the project (i.e., 16 years), even if the vehicle is sold abroad and continues to be used after the assumed lifetime, or if the vehicle battery is repurposed for stationary applications. This assumption thus adheres to the principle of a conservative estimate of the reduced emissions. For infrastructure projects (excluding charging and refueling infrastructure), a lifetime of 30 years is used in consultation with KfW, as referenced in (Wiener Linien 2022), (VGF 2017) and (Bock et al. 2020). For charging infrastructure, there are currently very few reliable figures. Considering the tax depreciation period of 6 to 10 years (IWW 2021) and a lifetime of 5 to 15 Jahren according to (EarthtronEV 2022), this methodology assumes a lifetime of 10 years.

For vehicles, the lifetime is determined from the total mileage and the annual mileage. These values are derived from TREMOD for road transport, while for other modes of transport, information from borrowers or other sources is used.

3.6 Attribution Factor

The attribution factor indicates what portion of a project's emissions is assigned to KfW. Two variants for the attribution factor of absolute emissions are explained in Section 2.5.1:

- On the one hand, the financing ratio can be considered on an annual basis. As the loan is repaid, the ratio decreases over time, which also reduces the attribution factor throughout the project's lifetime. Consequently, absolute emissions that occur later in the project are attributed to a lesser extent.
- On the other hand, there is the method of relating the loan amount (commitment amount or cash obligation) to the total investment amount. The resulting quotient is applied to the total emissions of the project to calculate the bank's share.

The method mentioned last was selected by KfW even before the start of the current project and is accordingly adopted for the Clean Transport methodology. It is represented in Equation IX and is applied analogously to relative emissions (Guidehouse 2023).

$$Attribution\ factor = \frac{Loan\ Amount\ (Commitment\ Amount\ or\ Cash\ Obligation)}{Total\ Value} \qquad \text{(IX)}$$

In the case of simultaneous financing of multiple measures, a uniform attribution factor is used for all measures within the same loan.

Since 2024, projects from KfW's Financial Cooperation (FC) business area can also be refinanced via green bonds. In financial cooperation, there are projects that involve co-financing between budget funds and KfW funds. A special case may arise in which the Federal Ministry for Economic Cooperation and Development subsidises the interest rate on a loan. The attribution of emissions in this special case is regulated seperately.

As described in Section 2.5.1, it should be considered when attributing relative emissions that infrastructure and vehicles generally cannot be looked at independently of one another. For instance, a new railway line only leads to emission reductions in combination with the trains operating on it, even if the latter are not financed by KfW. Therefore, when calculating the relative emissions of infrastructure measures, the entire system of infrastructure and vehicles is always accounted for. Subsequently, the resulting emission reduction would ideally need to be divided between the two subsystems. However, there is currently no method for this, and it was not possible to develop one within the current project. Thus, as is generally customary, no division between vehicles and infrastructure was made; that is, the relative emissions are attributed solely based on Equation IX, taking into account the loan amount and the total value of the current KfW project.

In project financing by KfW, it may occur that the investment or parts of it do not directly lead to GHG reductions, or that measures cannot be quantified due to a lack of data (see Chapter 4). An example of the former case is the financing of a project that includes both the expansion of the rail network and the renewal of a platform. The expansion of the rail network directly results in an increase in transport capacity and, consequently, a reduction in emissions, whereas the renewal of the platform does not lead to emission reductions, at least not immediately. Thus, the renewal of the platform contributes zero relative emissions to the calculation, and the loan amount spent for this purpose is considered accounted for. However, if a measure cannot be quantified because, for example, the applicant has not provided the necessary information, the measure is excluded, and the loan amount used for it is reported as not accounted for.

3.7 Summary of the Methodology

The previous sections have shown that all relevant greenhouse gases (CO_2, N_2O, and CH_4) and air pollutant emissions (NO_x, PM, CO, and NMVOC) are taken into account. In addition to TTW and WTT emissions, the GHG accounting also includes emissions from the provision of vehicles (MAT) and infrastructure (INFRA), whereas air pollutants are only considered tank-to-wheel.

The calculation is conducted ex-ante and requires the provision of project data by the borrower as well as default values, e.g., for emission factors.

The observation period is identical for both the project and BAU scenarios. For infrastructure projects, the lifetime is generally 30 years, while it is 10 years for charging infrastructure. For vehicle measures, it is calculated based on total mileage and annual mileage. Usage remains constant over the lifetime.

The relative emissions (emission reductions) are determined from the difference between the absolute emissions of the project scenario and the BAU scenario, which is designed to be forward-looking. The share of the relative emissions attributed to KfW financing is derived from the ratio of the commitment amount (or cash obligation) to the total investment amount.

4 Detailed Methodology Using the Example of the Sustainable Mobility Loan Program

4.1 General Assumptions and Notes

In the following chapter, the methodology presented in Chapter 3 is applied to specific project types. The approach is described in more detail, necessary specifications are added, and deviations from the general methodology are identified. This is done using the example of the "Sustainable Mobility" loan program, for which the relative GHG and air pollutant emissions were calculated in parallel for the program year 2022.

Additionally, based on this chapter, the data inquiry for the "Sustainable Mobility" program has been revised. Data is only requested from applicants when emission reductions for the affected measure need to be quantified, in order to minimize the effort for the applicants. Direct statements from borrowers regarding the total emission reduction are only used as a reference value (exception: digitalization measures).

To ensure a uniform calculation and to keep the effort for the applicants as low as possible, default values provided by ifeu are used in many places. These will be listed in the following sections for each purpose. Therefore, of the required input data, which can be derived from the equations, only those not marked as default values need to be provided by the applicants.

The following section addresses the input variable modal shift before discussing the individual project types. Subchapter 4.2 deals with infrastructure projects, subchapter 4.3 refers to vehicle-oriented projects, and subchapter 4.4 focuses on digitalization measures.

4.1.1 Modal Shift

The modal shift depends on many different factors and should therefore, if possible, be specified by the applicant and, preferably, be derived from surveys (so-called "stated preferences"). If the modal split is provided in the data query, the applicant has to specify the data source. If no entry is made, default values are used. These are based on the assumption that the modal shift corresponds to the current modal split for the relevant distance category, which was derived from (infas et al. 2018). In addition, induced traffic resulting from the project is taken into account. The modal shift is generally expressed as a percentage of transport performance (% pkm).

Depending on the project type, different modes of transport are relevant with regard to the modal shift. On the one hand, only relevant means of transport are queried; on the other hand, means of transport with similar emission factors are grouped together in the query as far as possible (e.g. local public transport). This is intended to simplify the completion of the questionnaire. Details on the vehicle categories used can be found in the following chapter.

Modal shift effects are considered for passenger transport projects, but not for freight transport projects. The reduction in emissions in freight transport is only achieved by changing the mode of transport. It is assumed that the choice of means of transport in freight transport is subject to economic considerations and limitations imposed by the infrastructure, which KfW financing cannot influence.

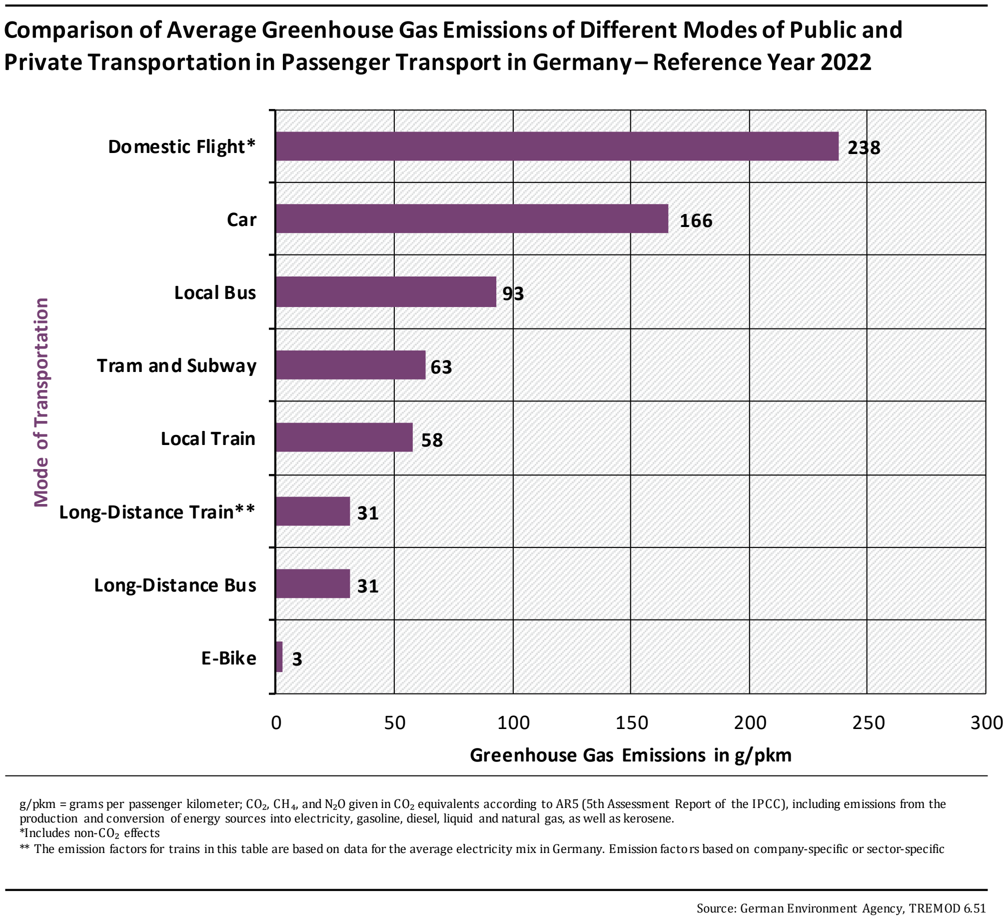

Figure 7: Comparison of average GHG emissions of individual modes of transport in passenger transport

Source: (UBA 2024), translated by ifeu

4.2 Infrastructure

4.2.1 Infrastructure for Active Mobility

Basic assumptions

The purpose "Infrastructure for Active Mobility" includes the following measures:

- Bicycle path/bike lane
- Footpath
- Combined bike and footpath

- Conversion in favor of climate-friendly infrastructure
- Bicycle parking facility (parking lot/parking garage)
- Green charging/refueling infrastructure

The effects of the two measures "Bicycle Parking Facility" and "Green Charging/Refueling Infrastructure" only indirectly lead to potential emission reductions. While new bicycle parking spaces and charging stations for e-bikes likely promote the use of active modes, these effects can only be quantified with extreme uncertainty. Accordingly, the impact of these measures is not quantified.

The first four measures listed can directly achieve a GHG effect by increasing the use of active modes. The resulting GHG and pollutant reductions will be quantified.

It is assumed that only passenger transport is noticeably affected by the infrastructure. The use of the infrastructure by cargo bikes should not have a significant effect on the transport performance of freight transport.

For the quantification of emission reductions, the mileage or transport performance of bicycles and pedestrians on the financed route is required. We assume that applicants can provide the number of cyclists or pedestrians who are expected to use the route additionally per day due to the construction measure. Therefore, the applicant does not need to specify the total number of trips on the infrastructure, but only the trips that are expected to be additional. Often, feasibility studies are conducted for such projects, which consider a zero case (without implementation) and a planned case with implementation. The difference in traffic volume between the two cases would correspond to the additional volume.

The transport performance required for calculating the relative emissions is determined by the number of additional trips/routes and the financed route length.

This approach may lead to a slight overestimation of the transport performance on the financed infrastructure, as, for example, a cyclist may turn onto another road halfway along the financed bike path and therefore does not fully utilize the route. Conversely, the distance traveled by the cyclist off the financed infrastructure is not taken into account, even though the trip would not have occurred without the financing. The effects of these two simplifications partially offset each other.

All measures follow the same calculation method and differ only in the emission factors and transport performances used over the lifetime.

For newly constructed or expanded paths, the GHG emissions resulting from the construction of the infrastructure are taken into account. However, pollutant emissions that occur during construction are not considered. Emissions arising from repurposing and modernization are also neglected. The reason for this is that these can involve very different construction measures, such as additional signs, marking lines, or, in extreme cases, a new road surface. While significant emissions may occur in the latter example, it is assumed that the construction measures are generally minor in most cases.

In the project scenario, in addition to the infrastructure emissions, the WTW GHG emissions and those for vehicle provision (MAT) are also considered. Only the small proportion of e-bikes leads to WTW emissions. Conventional bicycles and pedestrians do not have WTW-GHG emissions. For (e-)bikes, the emissions for MAT are also taken into account.

In the BAU scenario, while no additional emissions for the construction of infrastructure for active mobility arise, it is assumed that the additional cyclists and pedestrians from the project scenario would either not have made the trips at all or would have used a different mode of transport in the BAU scenario. Therefore, specific infrastructure and vehicle manufacturing emissions are also assumed for these trips in the BAU scenario: if the project had not been implemented, an alternative infrastructure would have needed to be expanded or maintained more frequently, and an alternative vehicle would have been in use.

In calculating the absolute emissions per scenario, only the additional trips and the infrastructure and vehicle manufacturing emissions are considered, as the remainder is eliminated in the calculation of the relative emissions. Direct pollutant emissions (TTW) do not occur in the project scenario, as these involve vehicles for active mobility. The absolute WTW emissions (GHG) in the project scenario are determined using the following equation:

$$E = T \cdot (N_{bike} \cdot l \cdot (e_{bike} + eMAT_{bike}) + l_{new} \cdot einf)$$

where

E	-	Absolute GHG-emissions [t]
T	-	Lifetime of the infrastructure [a]
N_{bike}	-	Number of additional cyclists [Trips/a]
l	-	Length of the total financed infrastructure [km]
e_{bike}	-	GHG emission factor WTW of e-bikes [g/pkm]
$eMAT_{bike}$	-	GHG emission factor for MAT of (e-)bikes [g/pkm]
l	-	Length of new and expanded financed infrastructure [km]
$einf$	-	GHG emission factor for new and expanded infrastructure [g/(km*a)]

The absolute WTW emissions (GHG) and TTW emissions (pollutants) in the BAU scenario are determined using the following equation:

$$E_i = N_{bike} \cdot l \cdot \sum_j S_j^{bike} \cdot (e_{i,j} + eMAT_j + einf_j) + N_{foot} \cdot l \cdot \sum_j S_j^{foot} \cdot (e_{i,j} + eMAT_j + einf_j)$$

where

E_i	-	Absolute emissions of the substance *i* [t]
N_{bike}	-	Number of additional cyclists [1/a]
N_{foot}	-	Number of additional pedestrians [1/a]
l	-	Length of the total financed infrastructure [km]
S^{bike}_j	-	Share of mileage of mode *j* with modal shift to cycling [%]

S^{foot}_j	-	Share of mileage of mode *j* with modal shift to pedestrians [%]
$e_{i,j}$	-	TTW or WTW-EF of compound *i* for mode *j* [g/pkm]
$eMAT_j$	-	Emission factor for MAT of transport mode *j* (only for *i*=GHG) [g/pkm]
$einf_j$	-	EF for infrastructure of transport mode *j* (only for *i*=GHG) [g/pkm]
j	-	Mode of transport [IMT, LPT, bicycle, pedestrian, induced]
i	-	compound [NO_X, PM, CO, NMVOC, GHG]

Input Variables

The input variables to be specified by the applicant are listed in the data request template for the credit programme.

Default Values

The following variables are established by ifeu:

- Lifetime of the infrastructure (T)
- GHG emission factor from infrastructure construction (*einf*)
- Emission factor of compound *i* for transport mode *j* ($e_{i,j}$)
- GHG emission factor from vehicle provision for mode *j* ($eMAT_j$)
- GHG emission factor for infrastructure for mode *j* ($einf_j$)
- Modal shift, if not specified in the application (M_j)

The lifetime of the infrastructure is assumed to be 30 years for all measures (Bock et al. 2020).

The GHG emissions for newly constructed or expanded routes are set at 2 t CO_{2eq}/km/a (Allekotte et al. 2020).

Since the same lifetime (30 years) is assumed for all measures, the emission factors from Table 6 apply uniformly. Additionally, the default shares for the modal shift are provided.

Table 6: Modal shift and EF – „Infrastructure for Active Mobility"

Shift to…	Mode of Transport	Share Modal Shift	GHG EF [g/pkm]			Pollutant EF [mg/pkm] TTW			
			WTW	MAT	INFRA	PM	NO_X	CO	NMVOC
Bicycle*	**IMT**	59%	95	37	5	2	63	359	47
	Public Transport	9%	38	5	9	0,4	30	7	1
	Bicycle*	9%	0,3	9	1	-	-	-	-

	Pedestrian	9%	-	-	0	-	-	-	-
	induced	14%	-	-	-	-	-	-	-
Foot	**IMT**	50%	95	37	5	2	63	359	47
	Public Transport	5%	41	5	8	0,5	32	7	1
	Bicycle*	14%	0,3	9	1	-	-	-	-
	Pedestrian	17%	-	-	0	-	-	-	-
	induced	14%	-	-	-	-	-	-	-

Source: Own evaluation based on (infas et al. 2018), (Allekotte et al. 2020) and TREMOD 6.43. Note: *A share of 14% e-bikes is included for bicycles (Jurczok et al. 2021).

4.2.2 Infrastructure for Local and Regional Public Transport and Other Rail Transport

The purpose "Infrastructure for Local and Regional Public Transport and Other Rail Transport" includes the following measures:

- Rail-bound infrastructure
- Stops and crossings
- Public transport facilities (e.g., signaling and control)
- Repurposing for public transport
- Infrastructure for the handling of goods

Only projects related to "rail-bound infrastructure" are quantified. "Stops and crossings" as well as "public transport facilities" contribute zero relative emissions to the calculation, as they typically exhibit either very indirect environmental impacts or their effects are already accounted for under the measure type rail-bound infrastructure when, for example, tracks and stops are constructed simultaneously. For the measures "repurposing for public transport" and "infrastructure for the handling of goods", no emission calculations can be conducted due to significant methodological issues and data availability challenges.

The focus is on passenger transport. The use of the infrastructure by freight trains is not quantified here.

Relevant for the emission calculation of rail-bound infrastructure is the type of measure. The following types are distinguished:

- New track construction
- Reactivation of a track
- Track modernization
- Electrification of an existing track

For the first two types of measures, it is assumed that a modal shift occurs. Therefore, the applicant has to specify the number of passengers transported on the new routes. From this and the route length, the transport performance can be derived. The applicant can indicate from which modes of transport the modal shift occurs (using percentage values related to transport performance). If this information cannot be provided, default values are used. This results in the transport performances on the new sections in pkm/a for the project scenario and the shifted transport performances per mode of transport for the BAU scenario.

The same calculation logic applies to the measure type "track modernization". However, it is generally assumed that modernization makes the railway more attractive but does not lead to a significant modal shift. This is a conservative estimate, as the term "modernization" is very broad and can indeed lead to shifts. Therefore, a modal shift is only calculated if the applicant explicitly indicates this. If no information is provided, the measure is accounted for with zero relative emissions in the calculation.

The electrification of existing tracks does not lead to shifts but rather to a change in the type of drive. This is taken into account in the emission calculations through the emission factors.

The emission factors for emissions (WTW, MAT, and INFRA for GHG, TTW for pollutants) for the BAU and project scenarios are derived from information provided by the applicant and data primarily from TREMOD. The applicant has to specify the usage area (urban or regional transport) as well as whether the route is electrified before and/or after the measure. The emission factors are given in g/pkm.

Additionally, GHG emissions for the provision of infrastructure are taken into account. For this, alongside the aforementioned points, the type of measure, usage area, and electrification, the number of tracks also have to be specified. For infrastructure related to regional transport, this results in emission factors in g/(route-km*a). In the case of urban transport in the project scenario and the shifted transport in the BAU scenario, different data availability applies. Here, the infrastructure emissions are given in g/pkm.

In the absolute emissions per scenario, only the additional trips and the infrastructure and vehicle manufacturing emissions are calculated, as the remainder is eliminated in the calculation of the relative emissions. The absolute emissions for GHG (WTW + MAT) and pollutants (TTW) in the project scenario are determined using the following equation:

$$E = T \cdot Apv \cdot \left(\left(L_{new} \cdot e_i + L_{react} \cdot e_j + L^{*}_{modern} \cdot e_k + L_{electr} \cdot e_{electr}\right) + (L_{new} + L_{react} + L^{*}_{modern} + L_{electr}) \cdot eMAT\right)$$

where

E	-	Absolute emissions for WTW, TTW and MAT in the project scenario [t]
T	-	Lifetime of the infrastructure [a]
Apv	-	Annual passenger volume on the route sections [passengers/a]
L_{new}	-	Length of newly built lines [km]
L_{react}	-	Length of reactivated lines [km]
L^{*}_{modern}	-	Length of modernized routes [km] - only if modal shift is given by the user, otherwise zero

L_{electr} - Length of existing electrified lines [km]

$e_{i,j,k}$ - EF for GHG (WTW) and pollutants (TTW) from rail depending on the electrification of the respective route [g/pkm]

i,j,k - Indication of whether line is electrified or not [-]

e_{electr} - GHG-EF (WTW) of an electric train [g/pkm] - only for GHG, for pollutants equal to zero

eMAT - EF for MAT of railroads [g/pkm] - only for GHG, zero for pollutants

Additionally, GHG emissions for the provision of infrastructure (INFRA) are also taken into account. Since the data structure of the emission factors for infrastructure varies depending on the usage area (urban or regional), the absolute emissions for the project scenario are calculated differently:

Regional Transport:

$$E_{inf} = T \cdot N \cdot (L_{new} \cdot e_{new,i} + L_{react} \cdot e_{react,j} + L^{*}_{modern} \cdot e_{modern,k} + L_{electr} \cdot e_{electr})$$

where

E_{inf} - Absolute emissions for infrastructure in the project scenario [t]

T - Lifetime of the infrastructure [a]

N - Number of tracks per line [-]

L_{new} - Length of newly built lines [km]

L_{react} - Length of reactivated lines [km]

L^{*}_{modern} - Length of modernized routes [km] - only if modal shift is given by the user, otherwise zero

L_{electr} - Length of existing electrified lines [km]

$e_{new,i}$ - EF for newly built tracks [g/track-km/a] - differs whether the line is electrified or not (*i*)

$e_{react,j}$ - EF for reactivated tracks [g/track-km/a] - differs depending on whether the line is electrified or not (*j*)

$e_{modern,k}$ - EF for modernized tracks [g/track-km/a] - differs whether line is electrified or not (*k*)

e_{electr} - EF for electrification of existing tracks [g/track-km/a]

Urban Transport:

$$E_{inf} = T \cdot Apv \cdot (L_{new} + L_{react} + L^{*}_{modern}) \cdot e_{inf}$$

where

E_{inf}	-	Absolute emissions for infrastructure in the project scenario [t]
T	-	Lifetime of the infrastructure [a]
Apv	-	Annual passenger volume on the route sections [passengers/a]
L_{new}	-	Length of newly built lines [km]
L_{react}	-	Length of reactivated lines [km]
L^{*}_{modern}	-	Length of modernized routes [km] - only if modal shift is given by the user, otherwise zero
e_{inf}	-	EF for infrastructure provision in urban transport [g/pkm]

The sum of the GHG emissions WTW, MAT, and INFRA results in the absolute GHG emissions in the project scenario.

The absolute GHG emissions (WTW + MAT + INFRA) and pollutant emissions (TTW) in the BAU scenario are determined using the following equation:

$$E = T \cdot (L_{new} + L_{react} + L^{*}_{modern}) \cdot Apv \cdot \sum_{j} MS_j \cdot (e_j + eMAT_j + einf_j) + T \cdot L_{electr} \cdot Apv \cdot (e_{notelectr} + eMAT_{Rail} + einf_{Rail})$$

where

E	-	Absolute emissions [t]
T	-	Lifetime of the infrastructure [a]
L_{new}	-	Length of newly built lines [km]
L_{react}	-	Length of reactivated lines [km]
L^{*}_{modern}	-	Length of modernized routes [km] - only if modal shift is given by the user, otherwise zero
L_{electr}	-	Length of existing electrified lines [km]
Apv	-	Annual passenger volume on the route sections [passengers/a]
MS_j	-	Share of transport performance of mode *j* in modal shift [%]
e_j	-	TTW or WTW-EF for traffic type *j* [g/pkm]

$eMAT_j$	-	Emission factor for MAT of transport mode *j* (only for GHG) [g/pkm]
$einf_j$	-	EF for infrastructure of transport mode *j* (only for GHG) [g/pkm]
$e_{notelectr}$	-	TTW or WTW-EF for non-electric railroads [g/pkm]
$eMAT_{Rail}$	-	Emission factor for MAT for rail (only for GHG) [g/pkm]
$einf_j$	-	EF for rail infrastructure (GHG only) [g/pkm]

Input Variables

The input variables to be specified by the applicant are listed in the data request template for the credit programme.

Default Values

The following quantities are provided by ifeu:

- Lifetime of the infrastructure (*T*)
- GHG emission factor from infrastructure construction (*einf*)
- WTW emission factors for mode of transport *j* (e_j)
- GHG emission factor from vehicle provision for mode of transport *j* ($eMAT_j$)
- GHG emission factor for infrastructure for mode of transport *j* ($einf_j$)
- Modal Shift, if not specified by the applicant (MS_j)

The lifetime of the infrastructure is assumed to be 30 years for all measures (see Chapter 3.5).

The GHG emissions for regional transport for newly constructed tracks are set at 20.9 t CO_{2eq}/track-km/year (without overhead line), derived from (Mottschall und Bergmann 2013). Based on the information provided in the source, an estimate for the reactivation of tracks is made at 12.3 t CO_{2eq}/track-km/year (without overhead line). The infrastructure costs for modernization can only be determined with high uncertainty, as the term is very broad. For simplification, half of the cost of new construction is assumed. Emissions from modernization are only considered if a modal shift is indicated by the applicant, as described above. An infrastructure cost of 3.1 t CO_{2eq}/track-km/year for the overhead line (electrification) can be assumed based on (Mottschall und Bergmann 2013).

The GHG emissions for infrastructure are taken from (Allekotte et al. 2020) for both urban rail transport and the modes of transport in the BAU scenario. A value of 14 g/pkm is assumed for new urban lines. There is no data available from (Allekotte et al. 2020) for reactivated and modernized lines. The INFRA emission factors for those measure types are assumed to be 8 and 7 g/pkm, respectively.

Since the same lifetime (30 years) is assumed for all measures, the emission factors for the BAU scenario from Table 7 apply uniformly. Additionally, the default shares for the modal shift are provided.

Table 7: Modal shift and EF – „Rail-bound infrastructure"

Usage type	Mode of trans-port	Share Modal Shift	GHG EF [g/pkm]			Pollutant EF [mg/pkm] TTW			
			WTW	MAT	INFRA	PM	NO_X	CO	NMVOC
Urban	**IMT**	65%	95	37	5	2	63	359	47
	Public transport (rail)	8%	24	3	14	0	17	3	1
	Public transport (road)	3%	60	7	2	1	60	14	1
	NMT*	10%	0	5	0	-	-	-	-
	Induced	14%	-	-	-	-	-	-	-
Regional	**IMT**	69%	95	37	5	2	63	359	47
	Public Transport – short-distance	11%	31	3	11	0	30	6	1
	Public Transport – long-distance	0%	12	1	12	0	3	1	0
	NMT*	6%	0	6	0	-	-	-	-
	Induced	14%	-	-	-	-	-	-	-

Source: Own evaluation based on (infas et al. 2018), (Allekotte et al. 2020) and TREMOD 6.43. Note: *Bicycles and e-bikes are also included in NMT.

The emission factors in Table 8 apply to the project scenario.

Table 8: Emission factors for the project scenario „Rail-bound infrastructure"

Type of usage	GHG EF [g/pkm]			Pollutant EF [mg/pkm] (TTW)			
	WTW	MAT	INFRA	PM	NO_X	CO	NMVOC
Urban (Tram/Subway)	23	5	14	-	-	-	-
Regional (LPT) – electric	20	1	X*	-	-	-	-
Regional (LPT) - Diesel	70	1	X*	4	298	59	22

Source: Own evaluation based on (infas et al. 2018), (Allekotte et al. 2020) and TREMOD 6.43. Note: * The calculation of GHG emissions for infrastructure in regional transport is based on the length of the routes.

4.2.3 Infrastructure for Climate-Friendly Road Transport

The purpose "Infrastructure for Climate-Friendly Road Transport" includes the measures

- Repurposing infrastructure,
- Electric road systems (ERS),
- Retrofitting of maintenance workshops, and
- Infrastructure for the handling of goods.

For these measures, no relative emissions are calculated, as their effect is either very indirect (retrofitting of maintenance workshops, contributes with zero relative emissions to the calculation) or they are difficult to quantify. The ERS technologies are so far away from regular use that, in agreement with KfW, no methodology was developed for this measure.

4.2.4 Green Charging/Fueling Infrastructure for Road and Rail

The following measures are considered under the purpose „Green Charging/Fueling Infrastructure for Road and Rail":

- Electric charging infrastructure, including the expansion of the power grid
- Refueling infrastructure (hydrogen)

Both measures follow the same calculation method and differ only in the emission factors and energy consumption used. The quantification is primarily based on the amount of energy supplied. This will be provided by the applicant or estimatedby ifeu. The absolute project emissions consist of the WTW and MAT emissions of the vehicles operated with the supplied energy. In the BAU (business-as-usual) scenario, reference vehicles with the same mileage as in the project scenario are considered, and their WTW and MAT emissions are determined. The infrastructure emissions for the charging/fueling infrastructure are not taken into account, as they are negligible compared to the emissions from operation (Helms et al. 2022). Furthermore, they likely do not differ significantly from those for the production of conventional refueling infrastructure, which further reduces their impact on the relative emissions.

The mileage is derived as follows from the amount of energy supplied:

$$ML = \frac{T \cdot En}{V}$$

where

ML - Mileage travelled with energy from the charging/fueling infrastructure [km]

T - Lifetime of the infrastructure [years]

En - Amount of energy supplied [MJ/year]

V - Energy consumption of vehicles powered by energy from the charging/fueling infrastructure [MJ/km]

The absolute WTW emissions (GHG) and TTW emissions (pollutants) are determined in the project and BAU (business-as-usual) scenario using the following equation:

$$E_i = ML \cdot \sum_j S_j \cdot e_{i,j}$$

where

E_i - Absolute emissions of compound *i* [g]

S_j - Share of fuel type *j* in mileage [%]

$e_{i,j}$ - Emission factor of substance *i* for fuel type *j* [g/km]

j - Fuel type [diesel, gasoline, electricity, hydrogen, natural gas, LPG]

i - compound [NO_X, PM, CO, NMVOC, GHG]

In addition, the absolute GHG emissions from the material provision (MAT) for traction batteries, H_2 tanks, and fuel cells are included:

$$EMAT = ML \cdot (eC + eT + eFC)$$

where

EMAT - Absolute GHG emissions from material provision [g]

eC - GHG emission factor from material provision for the battery [g/km]

eT - GHG emission factor from material provision for H_2 tank [g/km]

eFC - GHG emission factor from material provision for FC [g/km]

Input Variables

The input variables to be specified by the applicant are listed in the data request template for the credit programme. The energy consumption and emission factors used are determined based on the category of vehicles that predominantly use the infrastructure.

Default Values

The following quantities are provided by ifeu:

- Energy consumption of the vehicles operated with energy from the charging/fueling infrastructure (*V*)
- Share of fuel type *j* in the mileage (S_j)
- WTW or TTW emission factor of substance *i* for fuel type *j* ($e_{i,j}$)
- GHG emission factor from material provision for the battery (*eC*)
- GHG emission factor from material provision for the H_2 tank (*eT*)

- GHG emission factor from material provision for fuel cell (*eFC*)

For all quantified projects, assumptions had to be made regarding the amount of energy supplied. These are explained in Appendix 5.3.

4.2.5 Infrastructure for Climate-Friendly Water Transport

Basic Assumptions

The following measures are considered under the purpose "Infrastructure for Climate-Friendly Water Transport":

- Electric charging infrastructure for battery-electric ships
- Shore power connection
- Refueling infrastructure (hydrogen)
- Infrastructure for the handling of goods

The first three measures follow the same calculation method and differ only in the emission factors and energy consumption used. The quantification is primarily based on the amount of energy supplied, which is provided by the applicant. The absolute project emissions consist of the WTW and MAT emissions (only additional aggregates) of the ships operated with the supplied energy. In the BAU (business-as-usual) scenario, reference ships with the same mileage (or supplied energy in the case of the shore power connection) as in the project scenario are considered, and their WTW emissions are determined. As described in Section 3.3, average new ships are considered in the BAU scenario instead of the average of the future fleet.

The relative emissions resulting from infrastructure for the handling of goods depend heavily on factors that cannot be queried through an automated low-threshold inquiry, as one would have to know the impact on the overall system (How far are the handled goods transported? Which mode of transport would have been used without the handling infrastructure? Possibly a ship, just on a slightly shorter route?). For this reason, the decision was made not to quantify relative emissions from handling infrastructure.

The absolute WTW and MAT emissions (GHG) or TTW emissions (pollutants) are determined in the project scenario using the following equation:

$$E_i = T \cdot En \cdot (e_i + e_{MAT,i})$$

where

E_i	-	Absolute emissions of compound *i* [g]
T	-	Lifetime of the infrastructure [a]
En	-	Amount of energy supplied [MJ/year]
e_i	-	Emission factor of substance *i* for electricity or hydrogen (GHG: WTW, air pollutants: TTW) [g/MJ]

$e_{MAT,i}$ - MAT emission factor of substance *i* (only additional aggregates, only for GHG) [g/MJ]

i - compound [NO_X, PM, CO, NMVOC, GHG]

To calculate the emissions in the BAU (business-as-usual) scenario, the amount of diesel that would be necessary instead of the amount of electricity or hydrogen supplied in the project scenario is determined. This is then multiplied by the corresponding emission factor:

$$E_i = \frac{T \cdot En}{Ef} \cdot e_i$$

where

E_i - Absolute emissions of the compound *i* [g]

T - Lifetime of the infrastructure [a]

En - Amount of energy supplied [MJ/year]

Ef - Efficiency of a diesel drive/generator compared to electric operation (BEV, FCEV or shore power) [$MJ_{electric}/MJ_{Diesel}$] or [$MJ_{H2}/MJ_{Diesel}$]

e_i - Emission factor of substance *i* for electricity or hydrogen (GHG: WTW, air pollutants: TTW) [g/MJ]

i - compound [NO_X, PM, CO, NMVOC, GHG]

4.2.6 Infrastructure for Climate-Friendly Air Transport

Basic Assumption

The purpose "Infrastructure for Climate-Friendly Air Transport" includes the following measures:

- Charging infrastructure for aircraft
- Hydrogen refueling station for aircraft
- Ground power supply/fresh air supply
- Charging infrastructure for airport operations, including the expansion of the power grid
- Hydrogen refueling station for airport operations

The effects of the two measures "Charging Infrastructure for Aircraft" and "Hydrogen Refueling Station for Aircraft" are not quantified. Currently, there are only a few small electric propeller aircraft models with less than 10 seats. A commercial application of large electric aircraft, if it ever comes, will only be possible in several years to decades. The same applies to hydrogen-powered aircraft.

In the measure "Ground Power Supply/Fresh Air Supply", ground power serves to supply energy to the aircraft during the stationary phase, thus replacing the auxiliary power units

(APU) of the aircraft. Both stationary and mobile units with power supply are considered. It is assumed that ground power supply always includes climate control and ventilation of the aircraft cabins via Air Conditioning Units (ACU). It has to be indicated whether the financed ground power and fresh air supply replaces an old diesel ground power unit (GPU) or if it is installed additionally, thus replacing the use of an APU. For the calculation of emissions, the annual energy demand of the financed ground power and fresh air supply have to be provided.

In the project scenario, only the WTW emissions for GHG from the financed ground power and fresh air supply are calculated. The MAT and INFRA emissions are not considered, as they are negligible over the lifetime.

In the BAU scenario, for GHG, only WTW emissions are taken into account. On the one hand, the emissions from the replaced diesel GPUs are accounted for, and on the other hand, the emissions from the APUs that are avoided due to the additional ground power supply are considered. It is assumed that all GPUs and APUs provide the same annual amount of energy as in the BAU scenario.

Direct pollutant emissions occur when using APUs and are therefore only considered in the BAU scenario.

The absolute WTW emissions (GHG) in the project scenario are determined using the following equation:

$$E_i = T \cdot En \cdot e$$

where

E_i	-	Absolute GHG emissions [t]
T	-	Lifetime of the ground power supply [a]
En	-	Annual electricity demand of the financed ground power supply [kWh/a]
e	-	EF for electricity [g/kWh]

The absolute WTW emissions (GHG) and TTW emissions (pollutants) in the BAU scenario are determined using the following equation:

$$E_i = T \cdot En \cdot \eta_S \cdot \left(\frac{Rep_D}{Rep_D + Rep_{APU}} \cdot \frac{e_{D,i}}{\eta_D} + \frac{Rep_{APU}}{Rep_D + Rep_{APU}} \cdot \frac{e_{APU,i}}{\eta_{APU}}\right)$$

where

E_i	-	Absolute emissions of the compound *i* [t]
T	-	Lifetime of the units [a]
En	-	Annual electricity demand of the financed ground power and fresh air supply [kWh/a]
η_S	-	Efficiency of the ground power supply [-]

η_D - Efficiency of diesel-powered GPU [-]

Rep_D - Diesel GPUs are replaced [0-no, 1-yes]

Rep_{APU} - APU are replaced [0-no, 1-yes]

$e_{D,i}$ - TTW or WTW-EF of substance *i* for diesel [g/liter]

$e_{APU,i}$ - TTW or WTW-EF of substance *i* for APU (only for *i*=GHG) [g/liter]

η_{APU} - Efficiency of diesel-powered APU [-]

i - compound [NO_X, PM, CO, NMVOC, GHG]

In the measures "Charging Infrastructure for Airport Operations, including the Expansion of the Power Grid" and "Hydrogen Refueling Station for Airport Operations", it is assumed that the financed infrastructure serves solely to supply energy to ground vehicles. The impact of the expansion of the power grid is considered an indirect influence and is therefore not included in the emissions calculation. In contrast, it is assumed that the financed charging stations and refueling stations enable the use of BEVs and FCEVs and replace diesel vehicles.

Thus, in the project scenario compared to the BAU scenario, a technology shift occurs. The applicant has to provide the expected annual energy amounts for the calculation. In calculating the GHG emissions, in addition to the WTW emissions, the emissions from the additional material requirements of the supplied vehicles compared to diesel vehicles are also accounted for. The emissions from the construction of the infrastructure are not considered.

The absolute WTW plus MAT emissions (GHG) and TTW emissions (pollutants) in the project scenario are determined using the following equation:

$$E_i = T \cdot En_j \cdot (e_{j,i} + eMAT_j)$$

where

E_i - Absolute emissions of the compound *i* [t]

T - Lifetime of the infrastructure [a]

En_j - Annual energy demand [electricity: kWh/a, H_2: kg/a]

$e_{j,i}$ - TTW or WTW-EF of substance *i* for energy carrier *j* [g/kWh, g/kg]

$eMAT_j$ - MAT-EF of vehicles for energy source *j* (only for GHG) [g/kWh, g/kg]

i - compound [NO_X, PM, CO, NMVOC, GHG]

j - Energy source [electricity, H_2 gaseous, H_2 liquid]

In the BAU scenario, the same useful energy is required as in the project scenario; however, only diesel-powered ground vehicles are used. The absolute WTW emissions (GHG) and TTW emissions (pollutants) in the BAU scenario are determined using the following equation:

$$E_i = T \cdot En_j \cdot \eta_j \cdot \frac{e_{Diesel,i}}{\eta_{Diesel}}$$

where

E_i	-	Absolute emissions of the compound *i* [t]
T	-	Lifetime of the infrastructure [a]
En_j	-	Annual energy demand in the project scenario [electricity: kWh/a, H_2: kg/a]
η_j	-	Efficiency of vehicles with energy source *j* in the project scenario [-]
$e_{Diesel,i}$	-	TTW or WTW-EF of substance *i* for diesel [g/liter]
η_{Diesel}	-	Efficiency of diesel vehicles in the BAU scenario [-]
i	-	compound [NO_X, PM, CO, NMVOC, GHG]
j	-	Energy source [electricity, H_2 gaseous, H_2 liquid]

Input Variables

The input variables to be specified by the applicant are listed in the data request template for the credit programme.

Default Values

The following quantities are provided by ifeu:

- Ground Power:
    - Lifetime of the units (*L*)
    - Efficiency of diesel and electric GPUs/ground power (η_D, η_S)
    - Efficiency of APU (η_{APU})
    - Emission factor of substance *i* for energy carrier *j* ($e_{j,i}$)
    - Emission factor of substance *i* for APU ($e_{APU,i}$)
- Charging infrastructure and H_2 Refueling Stations
    - Emission factor of substance *i* for energy carrier *j* in ground vehicles ($e_{j,i}$)
    - MAT emission factor for GHG for energy carrier *j* in ground vehicles ($eMAT_j$)
    - Efficiency for energy carrier *j* in ground vehicles (η_j)
    - Efficiency of diesel-powered ground vehicles (η_{Diesel})
    - Emission factor of substance *i* for diesel ground vehicles ($e_{Diesel,i}$)

4.3 Vehicles

4.3.1 Vehicles for Active Mobility

Basic Assumptions

The purpose "Vehicles for Active Mobility" includes the following measures:

- (E-)Cargo bike (for goods transport)
- (E-)Bicycle
- E-scooter
- Other devices for active mobility

All measures follow the same calculation method and differ only in the emission factors and traffic performance over the lifetime.

For financed vehicles that are additional and do not replace an old vehicle, the WTW and MAT emissions are accounted for over the entire lifetime in the project scenario. Replacement vehicles do not need to be considered for determining the relative emissions, as they are identical in both the project and BAU scenarios and thus cancel each other out.

In the BAU scenario, it is assumed that for a financed vehicle that is newly acquired without replacing an old vehicle, trips that would otherwise have been made with other vehicles are replaced, i.e., there is a modal shift. As in the project scenario, the WTW and MAT emissions are taken into account.

The absolute emissions (GHG) in the project scenario are determined using the following equation. Direct pollutant emissions (TTW) do not occur in the project scenario, as these are vehicles for active mobility.

$$E = N_{add} \cdot TP \cdot (e + eMAT)$$

where

E - Absolute GHG emissions [t]

N_{add} - Number of additional financed vehicles [-]

TP - Traffic performance of a vehicle over its entire service life [pkm/vehicle] or [tkm/vehicle]

e - GHG emission factor WTW [g/pkm] or [g/tkm]

$eMAT$ - GHG emission factor MAT [g/pkm] or [g/tkm]

The absolute WTW emissions (GHG) and TTW emissions (pollutants) in the BAU scenario are determined using the following equation:

$$E_i = N_{add} \cdot TP \cdot \sum_j S_j \cdot (e_{i,j} + eMAT_j)$$

where

E_i - Absolute emissions of the compound *i* [t]

N_{add} - Number of additional financed vehicles [-]

TP - Traffic performance of a vehicle over its entire service life [pkm/vehicle] or [tkm/vehicle]

S_j - Share of mileage of transport mode *j* [%]

$e_{i,j}$ - TTW or WTW-EF of substance *i* for mode *j* [g/pkm] or [g/tkm]

$eMAT_j$ - Emission factor for MAT of transport mode *j* (only for *i*=THG) [g/pkm] or [g/tkm]

j - Mode of transport [IMT, public transport, bicycle, pedestrian, induced, LCV, HGV]

i - compound [NO_X, PM, CO, NMVOC, GHG]

Input Variables

The input variables to be specified by the applicant are listed in the data request template for the credit programme. The measure, vehicle type and the drive type determine the emission factors and lifetimes to be used.

Default Values

The following quantities are provided by ifeu:

- Traffic performance of a vehicle over its lifetime (*T*)
- Emission factor of substance *i* for transport type *j* ($e_{i,j}$)
- GHG emission factor from vehicle provision of transport type *j* ($eMAT_j$)
- Modal Shift, if not specified by the applicant (S_j)

The traffic performance of vehicles for active mobility over their lifetime and the GHG emission factors for MAT were taken from (Allekotte et al. 2020). The pollutant emission factors (TTW) and GHG emission factors (WTW) for the transport types in the BAU scenario come from TREMOD. The emission factors and traffic performances used for the project scenario are summarized in the following table.

Table 9: Traffic performance and emission factors in the project scenario – "Vehicles for Active Mobility"

Vehicle Type	Provided Traffic Performance	GHG-EF WTW	GHG-EF for MAT
Bicycle	15.000 pkm	-	9 g/pkm
E-Bicycle	25.000 pkm	3 g/pkm	11 g/pkm
E-Scooter	10.000 pkm	5 g/pkm	18 g/pkm
Other Devices*	10.000 pkm	5 g/pkm	18 g/pkm
Cargo Bike	1.650 tkm	-	104 g/tkm
E-Cargo Bike	1.650 tkm	94 g/tkm	212 g/tkm

Source: Own evaluation based on (Allekotte et al. 2020) and TREMOD 6.43. Note: * It is assumed to be a vehicle for passenger transport. Since the input is too unspecific, a conservative estimate is made, using the lowest value from bicycle, e-bicycle, and e-scooter.

If the applicant does not provide information on the modal shift resulting from the additional vehicles for active mobility, default values will be used. These were derived from (infas et al. 2018), (Bauer et al. 2022) and own assumptions regarding induced traffic.

For the BAU scenario, the following GHG emission factors and default shares for modal shift are used:

Table 10: Modal shift and GHG emission factors in the BAU scenario – "Vehicles for Active Mobility"

Transport Type	Traffic type	Share Modal Shift	GHG-EF WTW	GHG-EF for MAT
Passenger Transport: Bicycle, E-Bicycle, Other Devices	**IMT**	59%	135 g/pkm	37 g/pkm
	Public transport	9%	32 g/pkm	5 g/pkm
	Bicycle	9%	-	9 g/pkm
	Pedestrian	9%	-	-
	Induced	14%	-	-
Passenger Transport: E-Scooter	**IMT**	37%	149 g/pkm	37 g/pkm
	Public transport	15%	35 g/pkm	5 g/pkm
	Bicycle	13%	-	9 g/pkm
	Pedestrian	23%	-	-
	Induced	12%	-	-
Freight Transport: Cargo Bike, E-Cargo Bike	**LCV**	89%	574 g/tkm	99 g/tkm
	HGV 3,5-7,5t GVW	11%	496 g/tkm	40 g/tkm
	Induced	0%	-	-

Source: Own evaluation based on (Bauer et al. 2022), (infas et al. 2018), (Allekotte et al. 2020) and TREMOD 6.43. For LCV, an average load of 500 kg is assumed.

For the BAU scenario, the following pollutant emission factors are used:

Table 11: Pollutant emission factors in the BAU scenario – „Vehicles for Active Mobility"

Transport Type	Traffic Type	EF TTW [mg/pkm, mg/tkm]			
		PM	NO_X	CO	NMVOC
Passenger Transport	**IMT**	3	136	649	74
	Public Transport	1	61	12	2
Freight Transport	**LCV**	40	1.085	1.101	40
	HGV 3,5-7,5t GVWR	21	1.008	485	51

Source: Own evaluation based on **(infas et al. 2018)**, **(Allekotte et al. 2020)** and TREMOD 6.43. For LCV, an average load of 500 kg is assumed.

4.3.2 Vehicles for Local and Regional Public Transport

Basic Assumptions

The purpose "Vehicles for Local and Regional Public Transport" includes the following measures:

- Subway
- Suburban train
- Tram
- Train
- Bus
- Other vehicles in local and regional transport

The first five measures follow the same calculation method and differ only in the emission factors and traffic performance over the lifetime. The measure "Other vehicles in local and regional transport" is too unspecific to quantify relative emissions.

Emissions reductions can occur in two ways:

- The acquisition of additional vehicles leads to an improvement in the service and thus to a modal shift to the more climate-friendly public transport.
- Replacement acquisitions result in a reduction in GHG emissions when switching to a more climate-friendly drive. This is the case for buses and partly for trains, while for trams, subways, and suburban trains, electric vehicles are always replaced by other electric vehicles, which does not lead to any emissions reduction.

The absolute WTW emissions (GHG) and TTW emissions (pollutants) are determined in the project and BAU scenario (drive change) using the following equation:

$$E_i = N \cdot LM \cdot \sum_j A_j \cdot e_{i,j}$$

where

E_i	-	Absolute emissions of the compound *i* [g]
N	-	Number of financed vehicles [-]
LM	-	Lifetime mileage of a vehicle [km/vehicle]
S_j	-	Share of mileage of fuel type *j* [%]
$e_{i,j}$	-	Emission factor of substance *i* for fuel type *j* [g/km]
j	-	Fuel type [diesel, electricity, hydrogen, natural gas]
i	-	compound [NO_X, PM, CO, NMVOC, GHG]

In addition, for a pure drive change, the absolute GHG emissions from material provision (MAT) for the base vehicle, traction battery, H_2 tank and fuel cell are included:

$$EMAT = N \cdot (eB + C \cdot eC + m \cdot em + FC \cdot eFC)$$

$EMAT$	-	Absolute GHG emissions from material provision [kg]
N	-	Number of financed vehicles [-]
eB	-	GHG emissions from material provision for the base vehicle [kg/vehicle]
C	-	Net capacity of the traction battery [kWh]
eC	-	GHG emission factor from material provision for the battery in relation to net capacity [g/kWh]
m	-	Capacity of the H_2 tank [kg]
em	-	GHG emission factor from material provision for H_2 tank [kg/kg]
FC	-	Power of the fuel cell [kW]
eFC	-	GHG emission factor from material provision for FC [kg/kW]

It is assumed that hydrogen is only used in gaseous form.

In the case of the modal shift, the absolute BAU emissions (WTW and MAT for GHG, TTW for air pollutants) result from:

$$E_i = N \cdot LM \cdot O \cdot \left(\sum_k \sum_j M_k \cdot S_{j,k} \cdot e_{i,j,k} + \sum_k M_k \cdot eMAT_{i,k} \right)$$

where

E_i - Absolute emissions of the compound *i* [g]

N - Number of financed vehicles [-]

LM - Lifetime mileage of a vehicle [km/vehicle]

O - Average vehicle occupancy [persons/vehicle]

M_k - Modal shift of vehicle category *k* [%]

$S_{j,k}$ - Share of fuel type *j* in the mileage of vehicle category *k* [%]

$e_{i,j}$ - WTW or, for air pollutants, TTW emission factor of substance *i* for fuel type *j and* vehicle category *k* [g/pkm]

eMAT - GHG emission factor from material provision for base vehicle [g/pkm]

k - Vehicle category [pedestrian, bicycle, IMT, bus, tram and subway, LPT]

j - Fuel type [diesel, electricity, natural gas]

i - compound [NO_X, PM, CO, NMVOC, GHG]

Input Values

The input variables to be specified by the applicant are listed in the data request template for the credit programme. The vehicle type determines the lifetime performance and, for buses and trains, the emission factors to be used, taking into account the drive type.

Default Values

The following quantities are provided by ifeu:

- Share of fuel type *j* in the mileage (S_j)
- WTW or TTW emission factor of substance *i* for transport type *j* ($e_{i,j}$)
- GHG emissions from material provision for the base vehicle (*eB*)
- GHG emission factor from material provision for the battery based on net capacity (*eC*)
- GHG emission factor from material provision for H_2 tank (*eT*)
- GHG emission factor from material provision for fuel cell (*eFC*)
- Modal Shift, if not specified by the applicant (M_k)
- GHG emission factor from material provision for the base vehicle (*eMAT*)

The following values will be requested from the applicant in the future and will be provided by ifeu until then (for buses, trams, and subways):

- Net capacity of the transaction battery (*C*)
- Capacity of the H_2 tank (*m*)
- Power of the fuel cell (*FC*)
- Average occupancy of a vehicle (*O*)

The aforementioned default values are partly derived from TREMOD 6.43 and partly from other sources. These are documented in the associated Excel file.

The lifetime performance of buses was derived from TREMOD based on diesel vehicles. It is assumed that the same lifetimes are applicable to alternative drives, and the additional components (traction battery, fuel cell, hydrogen tank) are also depreciated over their lifetime. Table 12 summarizes the lifetime performances as well as the lifetimes in years (needed for emission factors).

Table 12: Lifetime and lifetime mileage – "Vehicles for Local and Regional Public Transport"

Vehicle Type	Lifetime Mileage		Lifetime	
Bus	880.307	km	18	a
Tram	2.000.000	km	28	a
Subway	3.000.000	km	35	a

Sources: Own evaluation based on TREMOD 6.43, (DVB 2023), (Badische Zeitung 2017), (Berliner Zeitung 2017), (ZfK 2019), (Seitzinger 2023), (Bremer Senat 2015), (Eurail Press 2023).

If the applicant does not provide information on the modal shift resulting from the additional vehicles for public transport, default values will be used. These were derived from (infas et al. 2018) and own assumptions regarding induced traffic and are presented in Table 13.

Table 13: Modal shift – „Vehicles for Public Transport and Regional Transport"

Traffic Type	Share Modal Shift
IMT	69%
Pedestrian Traffic	2%
Bicycle	4%
Bus	3%
Tram and Subway	3%

Local Rail Passenger Transport	6%
Induced	14%

Source: Own evaluation based on (infas et al. 2018) as well as own assumptions.

4.3.3 Vehicles for Long-Distance Public Road Transport

Basic Assumptions

Under the purpose "Vehicles for Long-Distance Public Road Transport", the measure "Long-Distance Bus" is considered. Emission reductions can occur in two ways:

- The acquisition of additional vehicles leads to an improvement in supply and thus to a modal shift from other modes of transport to the long-distance bus.
- Replacement acquisitions result in a reduction in GHG emissions when switching to a more climate-friendly drive.

The absolute WTW emissions (GHG) and TTW emissions (pollutants) are determined in the project and BAU scenarios (drive change) using the following equation:

$$E_i = N \cdot LM \cdot \sum_j S_j \cdot e_{i,j}$$

where

E_i - Absolute emissions of the compund *i* [g]

N - Number of financed vehicles [-]

LM - Lifetime mileage of a bus [km/vehicle]

S_j - Share of fuel type *j* in mileage [%]

$e_{i,j}$ - Emission factor of substance *i* for fuel type *j* [g/km]

j - Fuel type [diesel, electricity, hydrogen]

i - compound [NO_X, PM, CO, NMVOC, GHG]

In addition, the absolute GHG emissions from material provision (MAT) for the base vehicle, traction battery, H_2 tank, and fuel cell are included:

$$EMAT = N \cdot (eB + C \cdot eC + m \cdot em + FC \cdot eFC)$$

EMAT - Absolute GHG emissions from material provision [kg]

N - Number of financed vehicles [-]

eB - GHG emissions from material provision for the base vehicle [kg/vehicle]

C - Net capacity of the traction battery [kWh]

eC - GHG emission factor from material provision for the battery in relation to net capacity [g/kWh]

m - Capacity of the H_2 tank [kg]

em - GHG emission factor from material provision for H_2 tank [kg/kg]

FC - Power of the fuel cell [kW]

eFC - GHG emission factor from material provision for FC [kg/kW]

It is assumed that in buses, hydrogen is only used in gaseous form. In the case of a drive change, the GHG emissions from material provision for the base vehicle are not explicitly included, as they are identical in both the project and BAU scenarios and thus have no impact on the resulting relative emissions.

In the case of the modal shift, the absolute BAU emissions (WTW and MAT for GHG, TTW for air pollutants) result from:

$$E_i = N \cdot ML \cdot O \cdot \left(\sum_k \sum_j M_k \cdot S_{j,k} \cdot e_{i,j,k} + \sum_k M_k \cdot eMAT_{i,k} \right)$$

where

E_i - Absolute emissions of the compund *i* [g]

N - Number of financed vehicles [-]

LM - Lifetime mileage of a bus [km/vehicle]

O - Average occupancy of a vehicle [persons/vehicle]

M_k - Modal shift of vehicle category *k* [%]

$S_{j,k}$ - Share of fuel type *j* in the mileage of vehicle category *k [* %]

$e_{i,j}$ - WTW or, for air pollutants, TTW emission factor of substance *i* for fuel type *j and* vehicle category *k* [g/pkm]

eMAT - GHG emission factor from material provision for base vehicle [g/pkm]

k - Vehicle category [passenger car, LDPT, LPT, airplane, long-distance bus]

j - Fuel type [diesel, electricity, hydrogen]

i - compound [NO_X, PM, CO, NMVOC, GHG]

Input Values

The input variables to be specified by the applicant are listed in the data request template for the credit programme. In the BAU scenario, an average long-distance bus is compared to replacement vehicles, while additional vehicles are accounted for with a modal shift.

Default Values

The following quantites are provided by ifeu:

- Lifetime mileade of a vehicle* (*L*)
- Share of fuel type *j* in the mileage (S_j)
- WTW or TTW emission factor for substance *i* for fuel type *j* ($e_{i,j}$)
- GHG emissions from material provision for the base vehicle (*eB*)
- GHG emission factor from material provision for the battery based on net capacity (*eC*)
- GHG emission factor from material provision for H_2 tank (*eT*)
- GHG emission factor from material provision for fuel cell (*eFC*)
- Modal Shift, if not specified by the applicant (M_k)
- GHG emission factor from material provision for the base vehicle (*eMAT*)

The following quantities are to be queried from the applicant in the future and will be provided by ifeu until then:

- Net capacity of the traction battery (*C*)
- Capacity of the H_2 tank* (*m*)
- Power of the fuel cell* (*FC*)
- Average occupancy of a vehicle* (*O*)

The aforementioned default values come partly from TREMOD 6.43 and partly from other sources..

The lifetime mileage of long-distance buses was estimated to be 800.000 km and the annual mileage to be 160.000 km. It is assumed that these mileages are applicable to long-distance buses with alternative drives and that the additional components (traction battery, fuel cell, hydrogen tank) are also depreciated over their lifetime.

If the applicant does not provide information on the modal shift resulting from the additional long-distance buses, default values will be used. These were taken from (Allekotte et al. 2020) and are presented in Table 14.

Table 14: Modal shift – „Vehicles for Passenger Transport Long-Distance Road Traffic"

Type of Transport	Share Modal Shift
Car	38%
Long-Distance Rail Passenger Transport	30%
Local Rail Passenger Transport	14%
Airplane	4%
Long-Distance Bus	4%
Induced	10%

Source: (Allekotte et al. 2020).

4.3.4 Cars, Motorcycles, and Light Commercial Vehicles

Basic Assumptions

The following measures are considered under the purpose "Cars, Motorcycles, and Light Commercial Vehicles":

- M1 (Cars): Drive Change
- N1 (Light Commercial Vehicles up to 3,5 t): Drive Change
- L (Motorcycles): Drive Change

All measures follow the same calculation method and differ only in the emission factors and lifetime mileages used. The emissions resulting from the production and operation of a vehicle over its entire lifetime are accounted for. These are compared with the emissions that would arise from the operation of a reference vehicle with the same lifetime mileage (BAU scenario). .

The absolute WTW emissions (GHG) or TTW emissions (pollutants) per scenario are determined using the following equation:

$$E_i = N \cdot LM \cdot \sum_j S_j \cdot e_{i,j}$$

where

E_i - Absolute emissions of the compund *i* [g]

N - Number of financed vehicles [-]

LM - Lifetime mileage of a passenger car or LCV [km/vehicle]

S_j - Share of mileage of fuel type *j* [%]

$e_{i,j}$ - Emission factor of substance *i* for fuel type *j* [g/km]

j - Fuel type [diesel, gasoline, electricity, natural gas, LPG]

i - compound [NO_X, PM, CO, NMVOC, GHG]

In both the BAU scenario and the project scenario, the absolute GHG emissions from the material provision (MAT) for the traction battery are also included. The emissions from the material provision for the base vehicle are not considered, as they are nearly identical in both the project and BAU scenarios. The absolute MAT emissions in the project scenario are derived from the following equation:

$$EMAT = N \cdot eC$$

$EMAT$ - Absolute GHG emissions from material provision for traction batteries [t]

N - Number of financed vehicles [-]

eC - GHG emissions from material provision for traction batteries [kg/vehicle]

Input Variables

The input variables to be specified by the applicant are listed in the data request template for the credit programme. The type of vehicle (car, light commercial vehicle, or motorcycle) determines the lifetime mileage. Only battery electric vehicles are considered in the quantification (see above).

Default Values

The following quantities are provided by ifeu:

- Lifetime mileage of a car or light commercial vehicle (*L*)
- Share of mileage for fuel type *j* (S_j)
- Emission factor of substance *i* for fuel type *j* ($e_{i,j}$)
- GHG emissions from material provision for battery (*eC*)

The lifetime mileages were derived from TREMOD for diesel and gasoline vehicles. It is assumed that the same lifetimes are also applicable to alternative drives and that the additional components (traction battery) are also depreciated over their lifetime. Table 15 summarizes the lifetime mileages as well as the lifetimes in years.

Table 15: Lifetime and lifetime mileage – „Cars, Motorcycles, and Light Commercial Vehicles"

Vehicle Type	Lifetime Mileage		Lifetime	
Car	218.697	km	16	a
Light Commercial Vehicle	272.853	km	13	a

Source: Own calculation based on TREMOD 6.43.

The average share of mileage per fuel type in the BAU is calculated using the aforementioned average lifetimes of the vehicles in the fleet. In the BAU scenario, gasoline and diesel vehicles are predominantly used. Together with other combustion engines, these are grouped as ICEV. Hydrogen vehicles are not considered in the BAU. In contrast, BEVs have a significant share of the mileage. The mileage shares are as follows:

Table 16: Share of electric mileage in the BAU scenario – „Cars, Motorcycles, and Light Commercial Vehicles" (average values over the respective lifetimes)

Vehicle Type	Share of BEV		Share of ICEV	
Car	27	%	73	%
Light Commercial Vehicle	14	%	86	%

Source: Own evaluation based on TREMOD 6.43.

The TTW emission factors for pollutants and WTW emission factors for GHG for ICEV also correspond to the average over the mentioned periods from TREMOD (see Table 17). This explicitly takes into account that the fleet is also renewed in the BAU scenario, and thus improvements in pollutant emissions and GHG emissions occur independently of KfW financing.

Table 17: TTW and WTW emission factors – „Cars, Motorcycles, and Light Commercial Vehicles"

Vehicle Type	ICEV					BEV
	GHG	PM	NO_X	NMVOC	CO	Electricity
	g/km	g/km	g/km	g/km	g/km	MJ/km
Car	179	0,001	0,15	0,065	0,69	0,80
Light Commercial Vehicle	287	0,019	0,50	0,019	0,53	1,54

Source: TREMOD 6.43. Note: Arithmetic mean of the periods from 2022 to end of lifetime according to Table 15. Accounting boundaries: GHG: WTW; pollutants and electricity consumption: TTW.

The GHG emission factors for electricity are provided in Section 3.4.2. These are multiplied by the respective consumptions.

The MAT emissions are given in the following table.

Table 18: GHG emissions for material provision – „Cars, motorcycles, and light commercial vehicles“

Parameter		**GHG Emissions**	
eC	Traction Battery*	5060	kg CO_{2eq}/Vehicle

Source: (Biemann et al. 2024); Note: *identical values for cars and light commercial vehicles

4.3.5 Long-Distance Trains for Passenger Transport

In the purpose "Long-Distance Trains for Passenger Transport", emissions reductions can occur in two ways:

- The acquisition of additional vehicles leads to an improvement in the service and thus to a modal shift to the more climate-friendly long-distance public rail transport.
- Replacement purchases result in a GHG reduction when switching to a more climate-friendly drive. Since almost exclusively electric trains are already used in long-distance transport in Germany, the GHG reduction from new electric trains is very low.

The absolute WTW emissions (GHG) or TTW emissions (pollutants) are determined in the project and BAU scenarios (drive change) using the following equation:

$$E_i = N \cdot LM \cdot \sum_j S_j \cdot e_{i,j}$$

with

E_i - Absolute emissions of compound *i* [g]

N - Number of financed vehicles [-]

L - Lifetime mileage of a vehicle [km/vehicle]

S_j - Share of mileage of fuel type *j* [%]

$e_{i,j}$ - Emission factor of substance *i* for fuel type *j* [g/km]

j - Fuel type [diesel, electricity, hydrogen] *i* - compound [NO_X, PM, CO, NMVOC, GHG]

In addition, the absolute GHG emissions from the material provision (MAT) for the base vehicle, traction battery, H_2 tank and fuel cell are included:

$$EMAT = N \cdot (eB + C \cdot eC + m \cdot em + FC \cdot eFC)$$

EMAT - Absolute GHG emissions from material provision [kg]

N - Number of financed vehicles [-]

eB - GHG emissions from material provision for the base vehicle [kg/vehicle]

C - Net capacity of the traction battery [kWh]

eC - GHG emission factor from material provision for the battery in relation to net capacity [g/kWh]

m - Capacity of the H_2 tank [kg]

em - GHG emission factor from material provision for H_2 tank [kg/kg]

FC - Power of the fuel cell [kW]

eFC - GHG emission factor from material provision for FC [kg/kW]

In the case of the modal shift, the absolute BAU emissions (WTW and MAT for GHG, TTW for air pollutants) result from:

$$E_i = N \cdot ML \cdot O \cdot \left(\sum_k \sum_j M_k \cdot S_{j,k} \cdot e_{i,j,k} + \sum_k M_k \cdot eMAT_{i,k} \right)$$

where

E_i - Absolute emissions of compound *i* [g]

N - Number of financed vehicles [-]

LM - Lifetime mileage of a vehicle [km/vehicle]

O - Average occupancy of a vehicle [persons/vehicle]

M_k - Modal shift of vehicle category *k* [%]

$S_{j,k}$ - Share of fuel type *j* in the mileage of vehicle category *k [* %]

$e_{i,j}$ - WTW or, for air pollutants, TTW emission factor of substance *i* for fuel type *j* and vehicle category *k* [g/pkm]

eMAT - GHG emission factor from material provision for base vehicle [g/pkm]

k - Vehicle category [IMT, public transport road, public transport rail, aircraft]

j - Fuel type [diesel, electricity, natural gas]

i - compound [NO_X, PM, CO, NMVOC, GHG]

4.3.6 Ships for Passenger Transport

The following measures are considered under the purpose "Ships for Passenger Transport":

- Inland Navigation
- Sea and Coastal Shipping
- Measures to reduce fuel consumption (inland)
- Measures to reduce fuel consumption (sea and coast)

The methodology differs between two types of measures:

- New ships (measures: inland navigation and sea and coastal shipping) are compared in the BAU scenario with ships with conventional drives (average over the service life; in the foreseeable future, virtually only ships with conventional propulsion will be used). It is assumed that only drive changes are relevant, while effects from a possible modal shift are negligible.
- In the case of modernizations (measures to reduce fuel consumption), the status after modernization (project scenario) is compared with the status without modernization (BAU scenario).

In addition, different emission factors are provided for the following types of ships:

- Cruise Ship
- Day Trip Ship
- Ferry (Passenger Transport)
- Ferry (Passenger and Vehicle Transport)

For ferries that transport both passengers and vehicles relative emissions can for methodological reasons only be determined in the case of modernization, but not in the case of a new acquisition.

The absolute WTW emissions (GHG) or TTW emissions (pollutants) are determined in the project and BAU scenarios using the following equation:

$$E_i = N \cdot LM \cdot \sum_j S_j \cdot e_{i,j}$$

where

E_i - Absolute emissions of compound i [g]

N - Number of financed ships [-]

LM - Lifetime mileage of a ship [km/vehicle]

S_j - Share of mileage of fuel type j [%]

$e_{i,j}$ - Emission factor of substance *i* for fuel type *j* [g/km]

j - Fuel type [diesel, electricity, hydrogen, LNG]

i - compound [NO_X, PM, CO, NMVOC, GHG]

In addition, the absolute GHG emissions from the material provision (MAT) for the traction battery, H_2 tank, and fuel cell are included:

$$EMAT = N \cdot (C \cdot eC + m \cdot em + FC \cdot eFC)$$

EMAT - Absolute GHG emissions from material provision [kg]

N - Number of financed ships [-]

C - Net capacity of the traction battery [kWh]

eC - GHG emission factor from material provision for the battery in relation to net capacity [g/kWh]

m - Capacity of the H_2 tank [kg]

em - GHG emission factor from material provision for H_2 tank [kg/kg]

FC - Power of the fuel cell [kW]

eFC - GHG emission factor from material provision for FC [kg/kW]

4.3.7 Trains for Freight Transport

The purpose "Trains for Freight Transport" includes the following measures:

- Replacement of the traction type of the locomotive (drive change)
- Efficiency measures on the train

In the project scenario, for both measures, the emissions resulting from the production and operation of a train with the new locomotive or the efficiency measure over its entire lifetime are accounted for. These are compared to the emissions that would arise from the operation of a respective reference train with the same lifetime mileage (BAU). If both measures are financed, the efficiency improvements are included in the calculation, taking into account the number of financed (driving) cars and the drive technology. If only one efficiency measure is financed, the reported efficiency improvements refer to an average train from the BAU scenario.

For each application, both measures can be covered, so both have to be included simultaneously in the calculation of emissions reductions. The absolute WTW emissions (GHG) or TTW emissions (pollutants) for the project scenario are determined using the following equation:

$$E_i = N \cdot ML \cdot \sum_j S_j \cdot e_{i,j} \cdot \left(a_j \cdot GT^{b_j} + c_j\right) \cdot GT \cdot (1 - \alpha)$$

where

E_i	-	Absolute emissions of compound *i* [t]
N	-	Number of financed trains [-]
L	-	Lifetime mileage of a locomotive [km/vehicle]
S_j	-	Share of mileage of fuel type *j* [%]
$e_{i,j}$	-	Emission factor of substance *i* for fuel type *j* [g/MJ]
a_j, b_j, c_j	-	Consumption parameters per fuel type *j* and train weight [-]
GT	-	Train weight in gross tons [t]
α	-	Relative improvement in consumption due to efficiency measure [%]
j	-	Fuel type [diesel, electricity, hydrogen]
i	-	compound [NO_X, PM, CO, NMVOC, GHG]

In the project scenario, the absolute GHG emissions from the material provision (MAT) for the traction battery, H_2 tank, and fuel cell are also included. In the BAU scenario, it is assumed that for a financed locomotive with a pantograph, a catenary locomotive would have been acquired even without the financing. Therefore, no emission savings result from this financing. This represents a conservative estimate. In contrast, for financed battery-electric and hydrogen-powered locomotives, as well as dual-power trains (traction via electricity and diesel), it is assumed that these replace a diesel locomotive. If a catenary were available, a catenary locomotive would be used. However, since a different technology is financed in the project scenario, it can be assumed that no catenary is available, and thus a diesel locomotive would be used without financing. The absolute MAT emissions in the project scenario are derived from the following equation:

$$EMAT = N \cdot LM \cdot (C \cdot eC + m_k \cdot em_k + FC \cdot eFC)$$

$EMAT$	-	Absolute GHG emissions from material provision for additional aggregates [t]
N	-	Number of financed trains [-]
LM	-	Lifetime mileage of a locomotive [km/vehicle]
C	-	Net capacity of the traction battery [kWh]
m_k	-	Capacity of the H_2 tank with aggregate state *k* [kg]
FC	-	Power of the fuel cell [kW]

eC - GHG emission factor from material provision for battery in relation to net capacity [g/kWh]

em_k - GHG emission factor from material provision for H_2 tank for aggregate state *k* [g/kg]

eFC - GHG emission factor from material provision for fuel cell [g/kW]

k - Physical state of hydrogen (liquid or gaseous)

Input Variables

The input variables to be specified by the applicant are listed in the data request template for the credit programme.

Default Values

The following quantities are provided by ifeu:

- Lifetime mileage of a locomotive (*LM*)
- Emission factor of substance *i* for fuel type *j* ($e_{i,j}$)
- Consumption parameters per fuel type *j* and train weight (a_j, b_j, c_j)
- GHG emission factor from material provision for battery (*eC*)
- GHG emission factor from material provision for H_2 tank for state of aggregation *k* (eT_k)
- GHG emission factor from material provision for fuel cell (*eFC*)

The lifetime mileage of a locomotive is set at 4.5 million km (Handelsblatt 2013). If "efficiency measures on the train" is the only measure indicated, a reference train is defined as an average train for the next 30 years (lifetime of a locomotive from (Handelsblatt 2013)) according to TREMOD. The average share of mileage per fuel type of the reference train in the BAU is approximately constant at 96% electricity and 4% diesel. The TTW emission factors for diesel locomotives and WTW emission factors for the reference locomotives are calculated from the average over the next 30 years (Handelsblatt 2013) from TREMOD, see Table 19.

Table 19: TTW and WTW emission factors of the reference locomotives – "Trains for Freight Transport"

Drive Project Scenario	**Reference**	**Substance**	**System Boundary**	**EF**
Battery Electric, Fuel Cell, Dual-Power Train	Diesel	CO	TTW	0,088 g/MJ
Battery Electric, Fuel Cell, Dual-Power Train	Diesel	NMVOC	TTW	0,040 g/MJ
Battery Electric, Fuel Cell, Dual-Power Train	Diesel	NO_X	TTW	0,415 g/MJ

Battery Electric, Fuel Cell, Dual-Power Train	Diesel	PM	TTW	0,005 g/MJ
Battery Electric, Fuel Cell, Dual-Power Train	Diesel	CO_{2eq}	WTW	90 g/MJ
Electric (Catenary)	Electric (Caten-ary)	CO_{2eq}	WTW	68 g/MJ

Source: TREMOD 6.43. Note: Arithmetic mean of the period 2022 + 30 years. Catenary locomotives have no TTW emissions.

The energy consumptions are derived based on parameters from (Biemann et al. 2023). These are based on consumption per net ton-kilometer. The consumptions of diesel and fuel cell trains are derived using a surcharge factor from the consumption of electric trains.. Table 20 shows, for example, the consumption of a train with a weight of 1,900 gross tons.

Table 20: Consumption per drive for a train weight of 1,900 gross tonnes

	Consumption in MJ/km
Diesel	178 MJ/km
Electric	66 MJ/km
Hydrogen	125 MJ/km

The GHG emission factors for electricity and hydrogen are provided in Section 3.4.2. These are multiplied by the respective consumptions.

The MAT emissions are given in the following table.

Table 21: GHG emission factors for material provision – "Trains for Freight Transport"

Parameter		**Emission Factor**	
eC	Traction Battery*	92,4	kg CO_{2eq}/kWh
eT_g	Hydrogen Tank (Gaseous)	204	kg CO_{2eq}/kg H_2
eT_f	Hydrogen Tank (Liquid)	153	kg CO_{2eq}/kg H_2
eFC	Fuel Cell	24	kg CO_{2eq}/kW

Source: (Biemann et al. 2024). Note: *For the calculation of emissions, the gross capacity is relevant. The given EF refers to the net capacity. A factor of gross/net of 1.1 is assumed (Kramer et al. 2021).

4.3.8 Heavy Goods Vehicles for Road Freight Transport

The purpose "Heavy Goods Vehicles for Road Freight Transport" includes the following measures:

- Heavy Goods Vehicles (3,5 t < GVWR ≤ 7,5 t): Drive Change
- Heavy Goods Vehicles (GVWR > 7,5 t): Drive Change

Both measures follow the same calculation method and differ only in the emission factors and lifetime mileages used. The emissions resulting from the production and operation of a heavy goods vehicle (HGV) over its entire lifetime are accounted for. These are compared to the emissions that would arise from the operation of a reference vehicle with the same lifetime mileage (BAU).

The absolute WTW emissions (GHG) or TTW emissions (pollutants) per scenario are determined using the following equation:

$$E_i = N \cdot LM \cdot \sum_j S_j \cdot e_{i,j}$$

where

E_i	-	Absolute emissions of the compound *i* [t]
N	-	Number of financed HGV
LM	-	Lifetime mileage of a HGV [km/vehicle]
S_j	-	Share of mileage of fuel type *j* [%]
$e_{i,j}$	-	Emission factor of substance *i* for fuel type *j* [g/km]
j	-	Fuel type [diesel, electricity, hydrogen, natural gas]
i	-	compound [NO_X, PM, CO, NMVOC, GHG]

In both the BAU scenario and the project scenario, the absolute GHG emissions from the material provision (MAT) for the traction battery, H_2 tank, and fuel cell are also included. The absolute MAT emissions in the project scenario are derived from the following equation:

$$EMAT = N \cdot (C \cdot eC + T_k \cdot eT_k + FC \cdot eFC)$$

$EMAT$	-	Absolute GHG emissions from material provision for additional aggregates [t]
N	-	Number of financed HGV
LM	-	Lifetime mileage of a HGV [km/vehicle]
C	-	Net capacity of the traction battery [kWh]

T_k - H_2 tank with aggregate state *k* [kg]

FC - Power of the fuel cell [kW]

eC - GHG emission factor from material provision for battery in relation to net capacity [g/kWh]

eT_k - GHG emission factor from material provision for H_2 tank for aggregate state *k* [g/kg]

eFC - GHG emission factor from material provision for fuel cell [g/kW]

k - Physical state of hydrogen (liquid or gaseous)Input Variables

Input Values

The input variables to be specified by the applicant are listed in the data request template for the credit programme. The vehicle categories considered are listed in Appendix 5.4.

The type of vehicle and operation, as well as the permissible total weight, determine the lifetime mileage. To determine the TTW and WTW emission factors to be used, the type of drive is also required. The information on the drive and the sizing of the traction is needed to calculate the MAT EF.

Default Values

The following quantities are provided by ifeu:

- Lifetime mileage of an HGV (*LM*)
- Share of mileage for fuel type *j* (A_j)
- Emission factor of substance *i* for fuel type *j* ($e_{i,j}$)
- GHG emission factor from material provision for battery (*eC*)
- GHG emission factor from material provision for H_2 tank for state of aggregation *k* (eT_k)
- GHG emission factor from material provision for fuel cell (*eFC*)

The lifetime mileage of the HGVs was derived from TREMOD for diesel vehicles. It is assumed that the same lifetimes are also applicable to alternative drives and that the additional components (traction battery, fuel cell, hydrogen tank) are also depreciated over their lifetime. Table 22 summarizes the lifetime mileages as well as the lifetimes in years (needed for EF).

Table 22: Lifetime and lifetime mileage – "Heavy Goods Vehicles for Road Freight Transport"

Size class	Measure	Lifetime Mileage	Lifetime
Van*	HGV (3,5 t < GVWR ≤ 7,5 t)	272.853 km	13 a
Truck 3,5-7,5t	HGV (3,5 t < GVWR ≤ 7,5 t)	597.112 km	15 a
Truck 7,5-12t	HGV (GVWR > 7,5 t)	702.013 km	10 a

Truck >12t**	HGV (GVWR > 7,5 t)	758.025	km	9	a
Articulated Truck	HGV (GVWR > 7,5 t)	426.118	km	14	a
Semitrailer	HGV (GVWR > 7,5 t)	1.000.706	km	8	a

Source: Own evaluation based on TREMOD 6.43. Note: *For vans (3,5-7,5t), the lifetime mileage of light commercial vehicles is assumed. **All solo trucks >12t receive the same lifetime mileage due to insufficient details in the source data.

The average share of mileage per fuel type in the BAU scenario is calculated using the mean of the aforementioned lifetimes of the vehicles in the fleet. In the BAU scenario, diesel vehicles are predominantly used. Natural gas vehicles also have a small share. Both are grouped as ICEV. Hydrogen vehicles are not considered in the BAU scenario. In contrast, BEVs have a small share of the mileage. The mileage shares are as follows:

Table 23: Share of electric mileage in the BAU – "Heavy Goods Vehicles for Road Freight Transport" (average values over the respective lifetimes)

Size Class	Share BEV		Share ICEV	
Van*	16	%	84	%
Truck 3,5-7,5t	12	%	88	%
Truck 7,5-12t	20	%	80	%
Truck >12t**	4	%	96	%
Articulated Truck	1	%	99	%
Semi-Trailer Truck	5	%	95	%

Source: Own evaluation based on TREMOD 6.43. Note: *For vans (3.5-7.5t), the shares of light commercial vehicles are assumed. **For all solo trucks >12t, the same shares are used.

In the project scenario, it is simplistically assumed that 50% of the mileage for PHEVs is electric. The remaining mileage has the same emission behavior as the ICEV share of the reference vehicle from the BAU scenario.

The TTW emission factors for pollutants and WTW emission factors for GHG for ICEV, as well as the electricity consumption of BEVs and hydrogen consumption of FCEVs, are also calculated from the average of the mentioned periods from TREMOD, see Table 24. It is explicitly taken into account that the fleet is renewed in the BAU scenario, leading to improvements in pollutant emissions and consumptions. The (small) mileage shares of natural gas vehicles are also considered in the emission factors of ICEV.

Table 24: TTW and WTW emission factors – "Heavy Goods Vehicles for Road Freight Transport"

Size class	ICEV					BEV	FCEV
	GHG	PM	NO_X	NMVOC	CO	Electricity	H_2
	g/km	g/km	g/km	g/km	g/km	MJ/km	MJ/km
Van	322	0,02	0,55	0,01	0,40	1,5	3,2
Truck 3,5-7,5t	485	0,02	0,91	0,05	0,40	2,7	5,5
Truck 7,5-12t	568	0,02	0,99	0,04	0,39	3,0	6,2
Truck 12-14t	620	0,02	0,88	0,05	0,20	3,1	6,3
Truck 14-20t	700	0,01	1,02	0,03	0,49	3,5	7,2
Truck 20-26t	851	0,01	1,36	0,03	0,45	4,0	8,2
Truck 26-28t	942	0,01	1,32	0,03	0,32	4,5	9,3
Truck 28-32t	1032	0,02	1,39	0,04	0,36	5,0	10,2
Truck >32t	1077	0,02	1,41	0,04	0,37	5,3	10,8
Articulated Truck	973	0,01	0,80	0,03	0,34	4,6	7,9
Semi-Trailer Truck	991	0,01	0,55	0,03	0,14	4,7	9,5

Sources: ICEV from TREMOD 6.43, BEV and FCEV from (Jöhrens et al. 2022). Note: Arithmetic mean of the periods 2022 + lifetime according to Table 22. Accounting boundaries: GHG of ICEV = WTW, pollutants, electricity and hydrogen consumption = TTW.

The GHG emission factors for electricity and hydrogen are provided in Section 3.4.2. These are multiplied by the respective consumptions. The MAT emission factors are given in the following table.

Table 25: GHG emission factors for material provision – "Heavy Goods Vehicles for Road Freight Transport"

Parameter		Emission Factor	
eC	Traction Battery*	92,4	kg CO_{2eq}/kWh
eT_g	Hydrogen Tank (Gaseous)	204	kg CO_{2eq}/kg H_2
eT_f	Hydrogen Tank (Liquid)	153	kg CO_{2eq}/kg H_2
eFC	Fuel Cell	24	kg CO_{2eq}/kW

Source: (Biemann et al. 2024). Note: *For the calculation of emissions, the gross capacity is relevant. The given EF refers to the net capacity. A factor of gross/net of 1.1 is assumed (Kramer et al. 2021).

The applicant can optionally provide the size of the battery, fuel cell, and H_2 tank. If no information is provided, assumptions from (Jöhrens et al. 2022) will be used.

4.3.9 Ships for Freight Transport

Basic Assumptions

The following measures are considered under the purpose "Ships for Freight Transport":

- Inland Navigation
- Sea and Coastal Shipping
- Measures to reduce fuel consumption (inland)
- Measures to reduce fuel consumption (sea and coast)

The methodology differs between two types of measures:

- New ships (measures: inland navigation and sea and coastal shipping) are compared in the BAU scenario with ships with conventional drives (average over the service life; in the foreseeable future, virtually only ships with conventional propulsion will be used). It is assumed that only drive changes are relevant, while effects from a possible modal shift are negligible.
- In the case of modernisations (measures to reduce fuel consumption), the status after modernization (project scenario) is compared with the status before (BAU scenario).

The absolute WTW emissions (GHG) or TTW emissions (pollutants) are determined in the project and BAU scenarios using the following equation:

$$E_i = N \cdot LM \cdot \sum_j S_j \cdot e_{i,j}$$

where

E_i - Absolute emissions of the compund *i* [g]

N - Number of financed ships [-]

LM - Lifetime mileage of a ship [km/vehicle]

S_j - Share of mileage of fuel type *j* [%]

$e_{i,j}$ - Emission factor of compound *i* for fuel type *j* [g/km]

j - Fuel type [diesel, electricity, hydrogen, LNG]

i - compound [NO_X, PM, CO, NMVOC, GHG]

In addition, the absolute GHG emissions from the material provision (MAT) for the traction battery, H_2 tank, and fuel cell are included:

$$EMAT = N \cdot (C \cdot eC + m \cdot em + FC \cdot eFC)$$

EMAT	-	Absolute GHG emissions from the provision of materials [kg]
N	-	Number of financed ships
C	-	Net capacity of the traction battery [kWh]
eC	-	GHG emission factor from the provision of materials for the battery in relation to the net capacity [g/kWh]
m	-	Capacity of the H_2 tank [kg]
em	-	GHG emission factor from material provision for the H_2 tank [kg/kg]
FC	-	Power of the fuel cell [kW]
eFC	-	GHG emission factor from the provision of materials for the fuel cell [kg/kW]

4.4 Sustainable Information and Communication Technologies (ICT)

4.4.1 Digitalization for Sustainable Mobility

The purpose "Digitalization for Sustainable Mobility" includes the following measures:

- Data-driven solutions
- Digital networking
- Other digital solutions

No methodology is established for the GHG reductions caused by digitalization measures, as the effects of such measures are very difficult to estimate, and therefore many detailed project-specific details would be required for quantification.

Applicants are allowed to specify the GHG reduction themselves if a corresponding study is available. In this case, we suggest using the value provided by the applicants as an exception.

5 Appendix

5.1 List of Scope 3 Categories

Table 26: List of scope 3 categories

Upstream or downstream	*Scope 3 category*
Upstream scope 3 emissions	**1.** Purchased goods and services **2.** Capital goods **3.** Fuel- and energy-related activities (not included in scope 1 or scope 2) **4.** Upstream transportation and distribution **5.** Waste generated in operations **6.** Business travel **7.** Employee commuting **8.** Upstream leased assets
Downstream scope 3 emissions	**9.** Downstream transportation and distribution **10.** Processing of sold products **11.** Use of sold products **12.** End-of-life treatment of sold products **13.** Downstream leased assets **14.** Franchises **15.** Investments

Source: (WRI und WBCSD 2013)

5.2 Impact Chain/Scopes

The definition of the scopes according to (KfW Competence Centre Climate and Energy 2022) is illustrated in Figure 8.

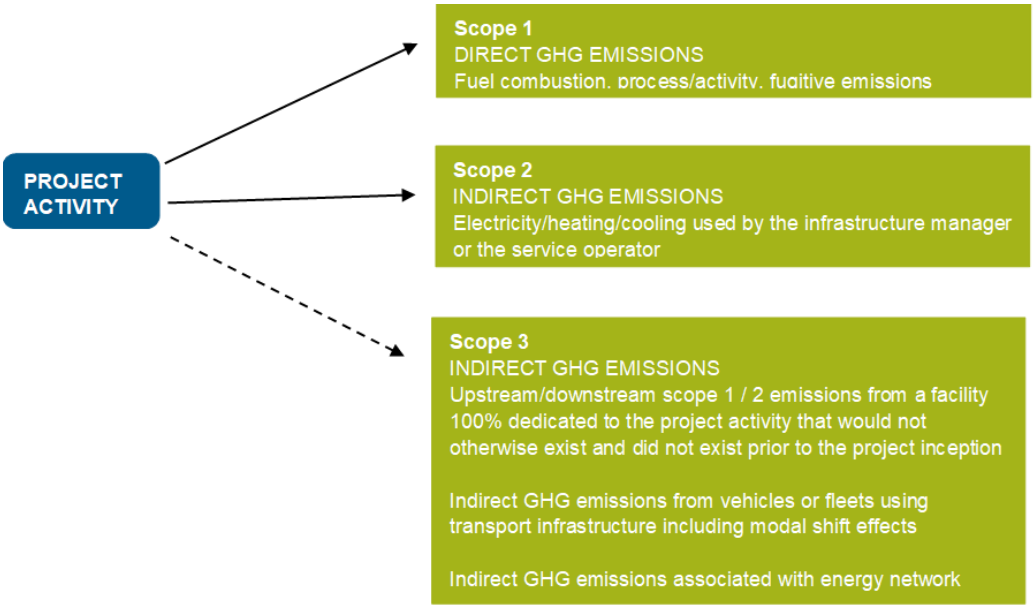

Figure 8: Definition of scopes for project financing

Source: (KfW Competence Centre Climate and Energy 2022)

According to (WRI und WBCSD 2013), for each year during the investment's duration, companies should consider the proportional scope 1 and scope 2 emissions of relevant projects (see Figure 9), that occur in the reporting year in scope 3 – category 15 (Investments). For example, if a financial institution provides equity or debt to a light bulb manufacturer, the financial institution has to account for the proportional scope 1 and scope 2 emissions of the light bulb manufacturers (i.e., direct emissions during production and indirect emissions from electricity consumption during production). The financial institution should also consider the scope 3 emissions of the light bulb manufacturer (e.g., scope 3 emissions from the use of the light bulbs sold by the manufacturer by consumers) if the scope 3 emissions are significant or otherwise relevant compared to other emission sources (WRI und WBCSD 2013).

CO_2e emissions from projects =

sum across projects:

∑ (scope 1 and scope 2 emissions of relevant project in the reporting year × share of total project costs (%))

Figure 9: Scope 1 and 2 for the emissions to be considered

Source: (WRI und WBCSD 2013)

For motor vehicle loans, (PCAF 2022) exemplifies the emissions to be considered: the annual emissions of the vehicles being financed:

- Scope 1: Direct emissions from fuel consumption in the vehicles
- Scope 2: Indirect emissions from electricity generation in electric vehicles (plug-in hybrids and fully electric)

The (IFI TWG 2015) also notes that for infrastructure projects, the scope 3 emissions related to the use of the infrastructure have to be considered in the GHG assessment of transport projects. However, in practice, these emissions are often overlooked: (EIB 2023) does not account for them in any transport sectors (road, rail, etc.).

According to (PCAF 2022) , financial institutions should indicate when they are unable to report the required scope 3 emissions due to data availability or uncertainty. For all sectors where PCAF does not yet mandate reporting on scope 3 emissions—see Table 27-, financial institutions should follow the GHG Protocol Corporate Value Chain (scope 3) Accounting and Reporting Standard and only disclose scope 3 emissions when they are relevant..

Table 27: List of sectors where inclusion of scope 3 emissions is required according to the EU TEG[1]

Phase-in period	NACE Level 2 (L2) sectors considered
For reports published in 2021 onwards	At least energy (oil & gas) and mining (i.e., NACE L2: 05-09, 19, 20)
For reports published in 2023 onwards	At least transportation, construction, buildings, materials, and industrial activities (i.e., NACE L2: 10-18, 21-33, 41-43, 49-53, 81)
For reports published in 2025 onwards	Every sector

Source: (PCAF 2022)

According to (PCAF 2022), investors in the transport sector are required to report the scope 3 emissions of borrowers and investee companies starting in 2023. However, the guidelines of the IFI already require that the transport-specific emission scope includes scope 3 emissions from vehicles operating on the financed physical infrastructure or from fleets departing from or arriving at a transport hub.

The KfW FC considers the scope 3 emissions (upstream emissions as well as infrastructure emissions and vehicle production emissions) of transport projects. The inclusion of scope 3 emissions is important for upstream emissions to enable a methodologically adequate comparison of technologies. In the field of electromobility, upstream emissions (emissions from electricity production and distribution) are accounted for in scope 2, whereas for vehicles with internal combustion engines, upstream emissions (fuel extraction, refining, and distribution) are covered under scope 3. Since a methodologically correct comparison of both drive technologies must always consider both direct emissions and upstream emissions, the KfW FC already includes this part of the scope 3 emissions (fuel supply chain) accordingly.

This approach is further emphasized by the fact that the EIB is currently examining whether to include upstream emissions from energy sources in its CO_2 accounting calculations. This

[1] The sector list of PCAF aligns with the phased approach for Scope 3 emissions as defined by the EU TEG and outlined in Article 5 of the supplementary Regulation (EU) 2016/1011 of the European Parliament and Council regarding the minimum standards for EU climate change benchmarks.

would encompass upstream emissions from fossil fuels, electricity generation, and biomass (EIB 2023).

According to (PCAF 2022), scope 3 emissions related to the manufacturing of vehicles, the delivery of vehicles to buyers, or the decommissioning of vehicles after use do not need to be accounted for, as these emissions are generally difficult to determine and tend to be marginal. However, if a financial institution wishes to consider the production emissions of new vehicles, it should report the emissions as follows:

- In the year of initial financing, the financial institution reports the production emissions of the respective vehicle as a lump sum under scope 3 emissions, while the operational emissions for that year are reported under scope 1 or scope 2 emissions.
- In the subsequent financing years, the financial institution does not report the manufacturing emissions of the respective vehicle but only the operational emissions under scope 1 or 2 emission.

This approach for scope 3 emissions applies only to new vehicles, not to used vehicle.

For all project types, the KfW FC methodology considered the emissions deemed relevant to enable an adequate comparison. This includes infrastructure as well as vehicle manufacturing emissions. For vehicle manufacturing, for example, the relevance of emissions from battery production was rated as high when accounting for a new electric car. To facilitate a comparison with another drive type (e.g., diesel car), the manufacturing emissions for all vehicles, including combustion engine vehicles, were included. Furthermore, the calculation methodology for emissions related to infrastructure needs to be discussed. The methodologies of PCAF and IFI require consideration of a realistic alternative to new infrastructure projects, such as the expansion of a road if the public transport project is not realized. Therefore, the emissions from the infrastructure are considered for both the scenario (realization of the public transport infrastructure project) and the BAU scenario (alternative road expansion). In the KfW FC methodology, these are accounted for as a lump sum per passenger-kilometer (pkm). The detailed classification of the emissions to be considered for the KfW FC is summarized in Table 28.

Table 28: Detailed emissions for transport projects differentiated by scopes

Phase	Emissions	Scope 1	Scope 2	Scope 3	Sequestration
Construction	Materials for Infrastructure			X	
	Energy Requirements for Infrastructure Construction	X			
	Materials for Vehicles and Energy Provision			X	
Operation	Financed Vehicles	TTW	WTT (only electricity)	WTT (except electricity)	
	Other Vehicles			WTW	
	Energy Requirements for Infrastructure, including heating/cooling	TTW	WTT (only electricity)	WTT (except electricity)	

Source: ifeu. Note: TTW: Tank-to-Wheel; WTT: Well-to-Tank; WTW: Well-to-Wheel.

According to (KfW Competence Centre Climate and Energy 2022), the shifting of CO_2 emissions should not be taken into account in the emissions calculation (e.g., the resale of old cars that have been exported from the country under study). Potential rebound effects are not explicitly or separately considered in the GHG methodology, but they should be part of project planning.

5.3 Assumptions for Calculating Sustainable Mobility Projects

Infrastructure for Active Mobility

- .

Green Charging/Fueling Infrastructure for Road and Rail

The amount of energy supplied was estimated as follows:

$$En = N \cdot d \cdot T \cdot En_1$$

where

En	-	Amount of energy released (over the service life of the infrastructure) [MJ]
N	-	Number of refueling/charging processes per day [1/day]
d	-	Number of operating days per year [days/year]
T	-	Service life of infrastructure [years]
En_1	-	Energy supplied during a tank/charging process [MJ]

The energy supplied during a refueling/charging process was estimated as follows:

$$En_1 = C \cdot p$$

where

C	-	Net capacity of the traction battery or capacity of the H_2 tank of the vehicle category primarily using the infrastructure [MJ]
p	-	Energy released per tank/charging process, in relation to the tank or battery size [%]

5.4 Vehicle Categories in Road Freight Transport

- Van (3,5-7,5t)
- Truck 3,5-7,5t
- Truck 7,5-12t
- Truck 12-14t
- Truck 14-20t
- Truck 20-26t
- Truck 26-28t
- Truck 28-32t
- Truck >32t
- Articulated Truck
- Tractor Unit

A van is defined here as a truck that is structurally identical to a light commercial vehicle (LCV) but has a higher permissible total weight (e.g., 5 t). In TREMOD, articulated trucks are further subdivided, but for simplification, only one weight class is considered here.

5.5 Default Values

Table 29: Energie consumption of road vehicles with alternative drive in the year 2022 with 50% load in MJ/km

Consumption	Car	LCV	Bus	Truck 12-14t[1]	Articulated truck
Electric vehicles (BEV)	0,8	1,5	6	3,1	4,7
H_2 fuel cell vehicles (FCEV)			10,8	6,3	9,5

Sources: TREMOD 6.43, ongoing ifeu project (not published), (Jöhrens et al. 2022), (BMDV 2021)

Table 30: WTW GHG emissions per distance traveled [g/km] by road vehicle category (mix of conventional energy sources)

Year	Car	LCV	Line bus	Truck 12-14[2]	Articulated truck
2022	223	324	1200	729	1029
2023	218	318	1186	719	1014
2024	210	311	1173	707	997
2025	203	305	1158	698	983
2026	195	298	1136	689	968
2027	187	288	1107	678	951
2028	178	277	1077	669	936
2029	169	264	1043	660	922
2030	159	248	999	648	903

[1] Other size classes are considered but are not listed here due to space constraints. All values are available in the corresponding Excel sheets for quantifying the NaMo funding 2022.
[2] Other size classes are taken into account but are not listed here due to space constraints. All values are available in the corresponding Excel sheets for quantifying the NaMo funding 2022.

2031	150	235	956	638	886
2032	140	220	911	626	864
2033	129	205	864	614	839
2034	118	189	812	600	809
2035	107	172	759	585	777
2036	97	156	702	569	743
2037	87	140	644	551	707
2038	78	125	584	532	670
2039	69	112	525	512	632
2040	60	99	465	490	593
2041	53	88	409	468	555
2042	46	77	357	446	516
2043	40	68	310	424	479
2044	34	59	267	403	440
2045	29	51	230	382	403
2046	24	45	197	361	365
2047	20	38	168	341	328
2048	17	33	142	322	291
2049	14	28	119	303	255
2050	11	24	99	285	219

Source: TREMOD 6.43

Table 31: Emission factors for motorized individual transport

Vehicle type	Emission factors [g CO_{2e}/pkm]	Distance traveled [Mill. Km]
2W (small)	72,8	4.856
2W (large)	125,6	9.636
Car	125,9	563.149
IMT (weighted)	125,5	

Source: TREMOD 6.51 (October 2023).

Table 32: WTW GHG emissions per transport performance [g/pkm] by vehicle category for public transport

Year	Local public transport rail (urban transport)	Local public transport (regional and long-distance)	Long-distance public transport rail (regional and long-distance)	Local public transport (road and rail)
2022	10	29	1	38
2023	9	27	1	36
2024	7	24	1	34
2025	6	23	1	33
2026	6	22	1	32
2027	5	21	1	31
2028	4	20	1	30
2029	4	19	1	29
2030	3	18	1	28
2031	3	17	0	27
2032	3	16	0	25
2033	3	15	0	24
2034	3	14	0	23
2035	3	14	0	21
2036	2	13	0	20
2037	2	12	0	18
2038	2	11	0	16
2039	2	10	0	15
2040	2	9	0	13
2041	2	8	0	12
2042	2	7	0	10
2043	2	6	0	9
2044	2	6	0	8
2045	2	5	0	7
2046	2	4	0	6
2047	1	4	0	5
2048	1	3	0	4
2049	1	3	0	4
2050	1	3	0	3

Source: TREMOD 6.43; Note: After 2050, the values for 2050 will be used consistently

The energy consumption of trains is derived based on the transported quantity; the values can be found in the corresponding Excel calculation sheet.

Table 33: INFRA emissions for rail infrastructure

Project types rail transport	EF	Unit
Regional and long-distance – new line (without overhead line)	20.877	kg CO_{2eq}/rail-km/a
Regional and long-distance – reactived line (without overhead line)	12.268	kg CO_{2eq}/rail-km/a
Regional and long-distance – modernized line (without overhead line)	10.439	kg CO_{2eq}/rail-km/a
Electrification/overhead line	3.139	kg CO_{2eq}/rail-km/a
Urban transport – new line	14	g CO_{2eq}/pkm
Urban transport – reactivated line	8	g CO_{2eq}/pkm
Urban transport – modernized line	7	g CO_{2eq}/pkm

Source: (Mottschall und Bergmann 2013), (Allekotte et al. 2020)

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